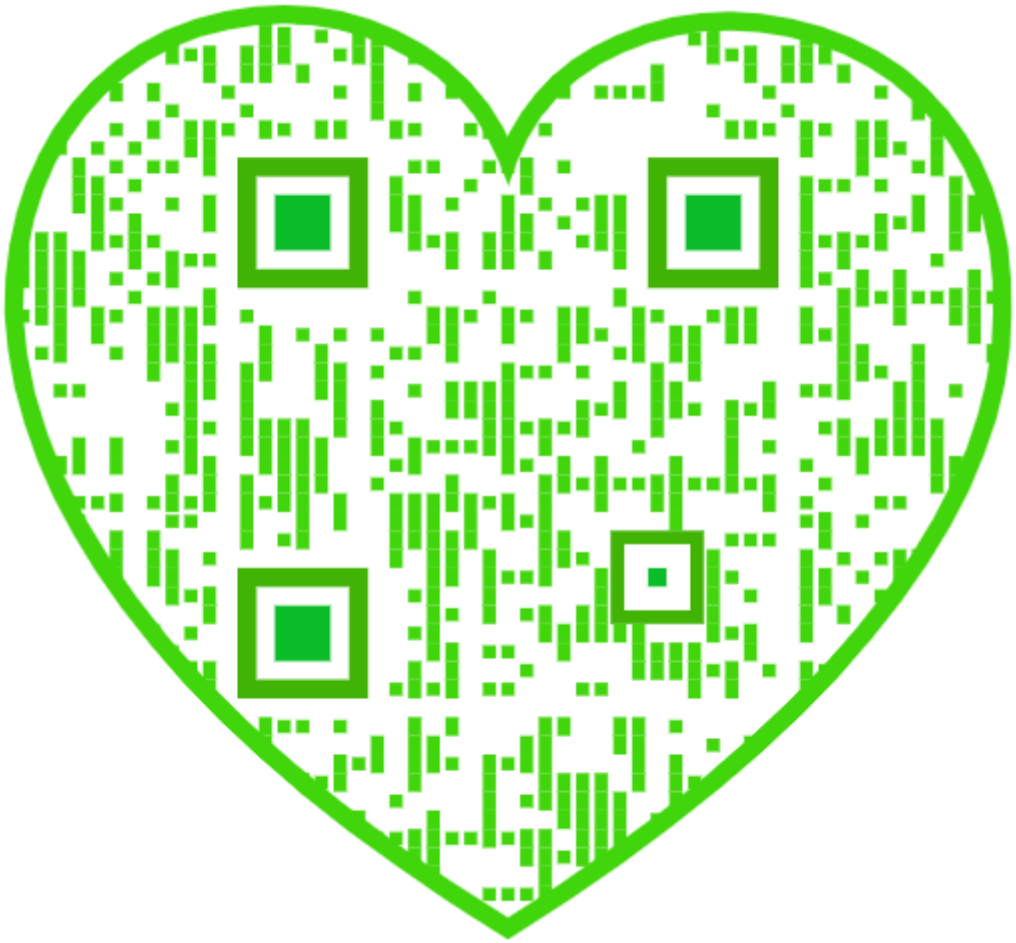

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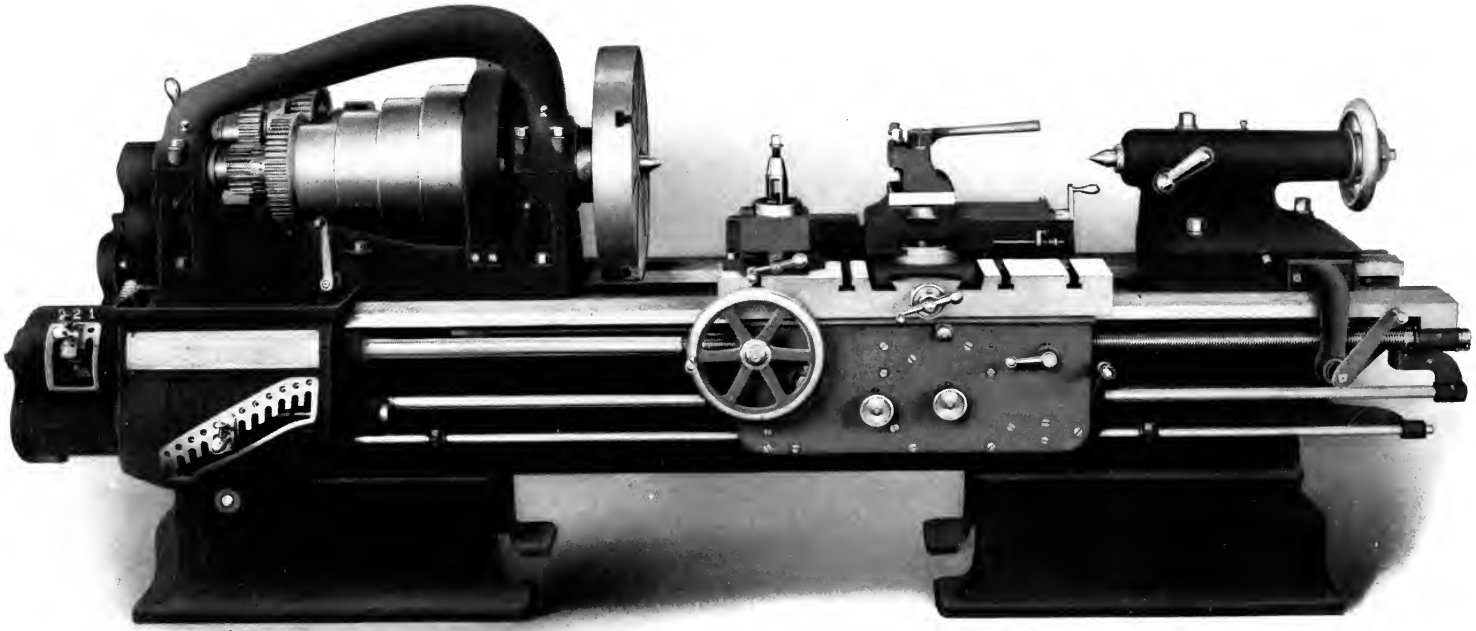

MODERN AMERICAN
LATHE PRACTICE

A NEW, COMPLETE AND PRACTICAL WORK ON

THE "KING OF MACHINE SHOP TOOLS," THE AMERICAN LATHE. GIVING ITS ORIGIN AND DEVELOPMENT. ITS DESIGN. ITS VARIOUS TYPES AS MANUFACTURED BY DIFFERENT BUILDERS, INCLUDING ENGINE LATHES, HEAVY LATHES, HIGH-SPEED LATHES, SPECIAL LATHES, TURRET LATHES, ELECTRICALLY DRIVEN LATHES, AND MANY OTHERS. LATHE ATTACHMENTS, LATHE WORK, LATHE TOOLS, RAPID CHANGE GEAR MECHANISMS, SPEEDS AND FEEDS, POWER FOR CUTTING TOOLS, LATHE TESTING, ETC.

BY

OSCAR E. PERRIGO, M.E.

Author of "Modern Machine Shop Construction, Equipment and Management," "Change Gear Devices," "The Milling Machine and its Work," "Gear Cutting," "Pattern Making and Molding," etc.

Illustrated by Three Hundred and Fifteen Engravings
Made from Drawings Expressly Executed for this Book

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PREFACE

THE aim of the Author in writing this book has been to present in as comprehensive a manner as may be within the limits of a single volume the history and development of the lathe from early times to the present day; to briefly discuss its effects upon manufacturing interests; to describe its practical use on various classes of work; and to compare in a representative, theoretical, and practical manner the Modern American Lathes as now built in this country.

In carrying out these aims the early history of the lathe is traced from its crude beginning up to the time when the foot-power lathe was the sole reliance of the early mechanic. Then the early history of the development of the screw-cutting or engine lathe is taken up and carried on to the middle of the last century. This is done to put the student and the younger mechanic in possession of the facts in relation to the origin and development of the lathe up to within the memory of many of the older mechanics of the present day.

The matter relating to the early history of the lathe is introduced for what seem to be good and sufficient reasons. If we are always to "commence where our predecessors left off" we shall miss much valuable information that would be very useful to us. A retrospective glance on what has been, a review of previous efforts, a proper consideration of the road by which we came, or by which earlier workers have advanced, is not only interesting but necessary to a full and complete understanding of the subject, and very useful to us in mapping out the course for our continued advancement in contributing our share in the development of mechanical science.

Following along these lines, the various types of lathes have

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been carefully classified, engravings and descriptions of the prominent American lathes are given, and their special features of design, construction, and use are pointed out and briefly commented upon.

It is a matter of much pride to every true American mechanic that this country produces so many really good and meritorious manufacturing machines, and in no line is this superiority more clearly shown than in the magnificent array of Modern Lathes.

This work brings these machines together in a comprehensive manner for the first time, and thus aims to add its quota to the present literature on this subject, and so make it valuable as a book of reference, alike to the student, the designer and the mechanic, as well as the manufacturer and the purchaser of Modern American Lathes.

THE AUTHOR.

January, 1907.

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INTRODUCTION

In the great measure of success that has been enjoyed, and the vast volume of wealth that has been produced in this, the most industrial of all countries, the manufacturing industries easily lead all other productive interests in which the people are engaged. While in the earlier years of American independence the chief dependence was upon the results of agriculture, the development of the resources of the country in time has placed manufactures at the head of the list so that in very recent years the value of manufactures has been nearly double the amounts of that produced by agricultural pursuits.

These results, like many others of a less notable character, commenced from small beginnings, and it has been by inborn mechanical talent, remarkable ingenuity, patient development, and tireless energy, that mechanical undertakings large and small have been developed, until the American mechanic leads the world in originality and practical achievement in our vast manufacturing enterprises.

When the early settlers, the Puritans of New England, labored under the restrictive and harassing laws of the mother-country, and under their administration were goaded and exasperated beyond endurance in many ways, not the least of which was being obliged to purhase all their manufactured articles from England at extortionate prices, or from other countries and still paying taxes to England, they rebelled and determining to buy no more foreign goods, set out, at first in very primitive and clumsy ways, to *make* such articles as were really necessary, and in magnificent self-denial to get along without those which they could not produce, they little realized that they were thus laying the foundations of the greatest manufacturing country in the world.

By their action they thus instituted probably the first industrial "boycott" in the history of the country, and one that has had

more important and far-reaching influences than any since its day.

It is true that the coming of the Pilgrims, their departure from the old country, was for religious freedom, but freedom soon meant vastly more to them than this, and with this larger conception of their opportunities, some of which were really forced upon them by adverse circumstances, came the inspiration of industrial as well as religious freedom. And the determined manner in which they set about their self-appointed task has amply demonstrated to their posterity and to the world their grasp of the possibilities and conditions of the situation as well as their breadth and nobility of character.

Thus sprang American manufactures into being, beginning with crude efforts to fashion those common objects of household necessity and daily use, which, clumsy though they were, yet served their practical purposes, to be supplanted later on by those more improved in form, design, and workmanship and better adapted to the uses for which they were made. The primitive successes of these early efforts led to greater endeavors, and the ingenuity displayed where "necessity was the mother of invention" was naturally developed into a still broader usefulness when the time came that necessities having been reasonably provided for, luxuries were thought necessary in the higher plane of living to which the people in due course had advanced.

And so it came about that the rude and crude beginnings in which the early mechanic performed his work in his own house outgrew these homely facilities and he built small shops, frequently in the gardens or back yards of the dwellings. These gradually enlarged; then came the necessity for still greater facilities, and buildings were erected quite independent of the home surroundings and two or more men were associated as manufacturers, and these became in due course of time the machine shops and the factories, which have multiplied many hundreds of times, not only in numbers and in value, but in influence and in importance, until to-day our country stands the leading manufacturing nation of the earth. And this may be said, not only as to the volume and the value of her manufactured productions, but also as to their great range and diversity of kind and degree. One after another

the American mechanic has taken up the work formerly monopolized by this country or that, failing perhaps at first, but always progressing, always advancing, until by native ingenuity and tireless energy all obstacles have been surmounted, all difficulties brushed aside, new industries spring into being and other "victories of peace greater than the glories of war" are added to the credit of the American mechanic and his ever ready and ever confident partner, the American manufacturer and capitalist. And to this combination, each confident of and faithful to the abilities of the other, and each in his own sphere of usefulness, is due the immense success of the manufacturing American of to-day.

In the early stages of manufacturing in this country all the tools and appliances were of a very crude and primitive kind and consisted mainly of a limited number of hand tools that had been brought with them from the old country, and occasionally a hand lathe of moderate dimensions, operated by foot-power. Yet with even these few facilities much important work was accomplished in the way of useful machines such as the flax and woolen spinning wheels and their accessories, and the wooden looms in which the yarn thus prepared was woven into the coarse but excellent cloth of these early times.

Then with the few tools and meager facilities possessed by them these old-time mechanics proceeded with practical common sense, ingenuity, and patience to design and construct other tools and machines such as by the necessities of occasion was manifest, and the increasing demands for them required better tools, better machinery, and facilities of a wider scope. The mechanic was then, as now, equal to the emergencies of the situation in which he found himself, and from small beginnings, and many of the parts of his machines made of wood, for lack of forge and foundry facilities, particularly the latter, has developed the machine tools of the present day.

The lack of facilities for making iron castings was very early felt, and history tells us that as early as the year 1643 John Winthrop arrived in this country from England, bringing with him the necessary number of skilled workmen for this purpose, and built a small iron foundry in Lynn, Mass.; and the fact that the first casting

produced was "a small iron pot holding about a quart" shows that the foundry was of very moderate capacity, and it is very likely that the blast used in melting the iron was produced by a hand bellows, as the blacksmith forge had preceded the foundry here, as it did, probably, in all other countries. The quart pot was cast from iron "made from native ore," although we do not know where they obtained it; probably from some place in the vicinity where it was found in small quantities. From this small beginning there was very little progress made for a considerable time in enlarging either the original scope of the work or in increasing its facilities, so far as we have any record. In 1735, nearly one hundred years later, we know that an iron foundry was built in the little town of Carver, Mass., and that a second one was put up in the same town in 1760, although we do not know the reason for this second one coming into existence in the same town unless it was that the first one had been destroyed by fire. However, it was in this second foundry that the historic "Massachusetts Tea-kettle" was cast. We do know that still another foundry was built in this town in 1793 and that this was burned down in 1841. Thus early did the custom begin, which is still in vogue in eastern Massachusetts, of devoting the energy of a town to one line of manufacture.

While these events and evidences of mechanical progress were taking place, the active minds of ingenious workmen were busily engaged in solving the practical problems of the growing demands made upon the shops and embryo manufactories engaged in supplying the wants of the people. New methods of manufacture, by which the quality as well as the quantity turned out could be improved, were demanded. This led to the demand for more machinery, which in turn led to the demand for better machines for the use of the mechanic, or for what we have come to know as machine tools. In the meantime the main reliance had been upon the ancient foot lathe, and with it much of their mechanical work had been accomplished. It had been improved in various ways, both in its design and in the materials of which it was constructed, and with the use of water-power for driving the machinery for manufacturing operations the lathe had become of greater usefulness by being driven in the same manner. Yet from the first it main-

tained its prominence as the first of the machine tools and the one which made all of the others that came after it possible of construction and useful in their several and respective spheres.

In the great scheme of manufacturing and the immense industrial problem of supplying the wants of the people in this respect by modern manufacturing plants equipped with all that is latest and best in machinery, it should be said that at the very basis and foundation of the whole stand the modern machine tools; that it is to the great and important development of these that we owe, primarily, our industrial prosperity as a nation. And to them may be easily traced the gradual upward tendency of the mechanic from the hard physical toil and laborious work of early days to the immeasurably lighter exertions made possible by the highly developed condition of the automatic machines of the present day. It has been, as was said in the outset, a victory of mind over matter, wherein *brains* have won where the *hands* made little advance; *ideas* developed wonderful mechanisms that have revolutionized the earlier methods of manufacturing, raised the standard of mechanical excellence beyond what was thought possible years ago, and at the same time reduced the cost to a fraction of its former amount. But to attain these marvelous results many machines have been required. All conceivable types and styles, and for an almost endless variety of purposes, have been designed, built, and perfected until hardly a possible mechanical operation is performed without the aid of a machine, frequently special in its design and automatic in its action, is brought into use, performing the work with surprising speed and wonderful accuracy.

The construction and perfection of all this magnificent array of highly developed machinery has only been made possible through the use of the machines for the use of the machinist, the machine tools of the present day, which must first have been perfected and adapted to the many needs and requirements which the advanced state of mechanical science demanded. These machine tools were made possible by the earlier examples of the most simple devices in this direction, chiefly, in our own time, the foot lathe, by which many of the earlier tools and machines were for the most part built; and as new uses for it were found new devices, attach-

ments, and accessories were devised and applied, and in this gradual development and improvement in its design, its construction, and the materials of which it is built, the early and crude foot lathe has become the magnificent machine of the present day, and in which the American mechanic takes a just and pardonable pride.

As to how this development progressed will be discussed in the opening chapters, and it is hoped that it will be found interesting to every American mechanic and particularly to the apprentice who is about to start out with learning the honorable trade of a machinist, and the student who would know from whence our modern machine tools were derived, that he may perhaps, in due time, become one of those who shall aid in their further development and perfection, as well as to the elder mechanic who uses these machines, and the mechanical engineer who is busy with their present development. It is always profitable to take a retrospective glance at the former state and condition of the matter upon which we are engaged, in order that we may not only realize from whence came the models built by the men who came before us, and to draw therefrom an inspiration for our own best efforts, but knowing the mistakes that have been made by others, to seek to avoid repeating them in our own experiences, our experiments and our designs by which we seek to add to the sum total of mechanical knowledge and improvement.

CHAPTER I

HISTORY OF THE LATHE UP TO THE INTRODUCTION OF SCREW THREADS

Tracing early history. The lathe was the first machine tool. The origin of the lathe. An old definition of turning. The first record of turning operations. Another old-time definition of turning. English classification of lathes. The earliest form of the lathe proper, or the old "Tree Lathe." The Asiatic wood turner. The "Springpole" lathe. The "Fiddle-bow" lathe. The essential features of a lathe. The balance-wheel applied to a lathe. The crank, connecting rod and treadle applied to a lathe. Origin of the term "Pitman." A foot lathe built by the Author. Its detailed construction. A foot lathe with the balance-wheel located over-head. The friction clutch for foot-power machines.

THE subject of the present work being the lathe and its work, and more particularly its design, construction, and development in our own country and in recent years, and as briefly comprised in our title of Modern American Lathe Practice, our efforts will be directed, first, to a brief notice of its origin and early development and use as a simple hand lathe; second, to its more modern development as one of the most important machine tools in the equipment of machine shops; and, third, to the various modifications of it, following its development through all its various forms and for the diversity of manufacturing purposes to which it has been adapted up to its present degree of efficiency.

In considering a subject of the vast importance of the modern lathe and its far-reaching influence upon the mechanical world of to-day, it cannot but be interesting to go back to its early history and to trace its progress and development from as far back as we have any authentic knowledge, and step by step to note the changes in its form and usefulness as the mind of the early mechanic developed, new requirements manifested themselves, and improvements in design, construction, tools, and attachments were devised to meet the growing needs.

It is conceded that of all the machines employed by the mechanic to aid him in his work the *lathe* holds the honor of having been the *first* machine tool. From it, in one way or another, all other machine tools have been developed; as they are, practically considered, but modifications of it, or special tools for doing quicker and better, the several operations which may be, and formerly were, performed upon the lathe, as we shall later on have occasion to describe and illustrate.

At present we will look into the origin of the lathe and then trace its gradual evolution and development up to comparatively recent years, say an hundred years or so ago, as their development into anything like mechanical importance has been confined to the last century which has been so remarkable in this respect.

Upon referring to the older records on the subject of lathes and their uses we find this statement: "Turning is the art of shaping wood, metal, ivory, or other hard substances into forms having a curved (generally circular or oval) transverse section, and also of engraving figures composed of curved lines upon a smooth surface, by means of a machine called a *turning-lathe.* This art is of great importance and extensive application in mechanics, the most delicate articles of luxury and ornament, equally with the most ponderous machinery, being produced by it. The art of turning dates from a very early period, and Theodorus of Samos, about 560 B.C., is named by Pliny as its inventor; but long before this period, the *potter's* wheel, the earliest and simplest form of turning-machine, was in general use, as is evidenced by numerous references in Holy Writ."

Again we read in an old-time definition of what turning really consists of: "The immense variety of work performed by turning-machines necessitates great variations in their construction; but mode of operation is always the same, and consists essentially in fixing the work in position by two pivots, or otherwise, causing it to revolve freely around an axis of revolution, of which the two pivots are the poles, and holding a chisel or other cutting-tool so as to meet it during its revolution, taking care that the cutting-tool be held firmly and steadily, and moved about to different parts of the work till the required shape is obtained."

In England the various methods of driving a lathe gives a

classification to them somewhat different from that in this country. Hence the following: "Lathes are divided, with respect to the mode of setting them in motion, into *pole* lathes, *foot* lathes, *hand-wheel* lathes, and *power* lathes; and with respect to the species of work they have to perform, into *center* lathes, which form the outside surface, and *spindle, mandrel,* or *chuck* lathes, which perform hollow or inside work, though this distinction is for the most part useless, as all lathes of good construction are now fitted for both kinds of work." Another peculiarly English idea in reference to lathes is this: "*Bed* lathes are those used by turners in wood, and *bar* lathes for the best sort of metal work; and the small metal center lathe employed by watchmakers is known as a *turn-bench.*"

The earliest form of a lathe proper, that is, "a machine for shaping wood into forms having a curved, and generally a circular transverse section, by the action of a chisel or other cutting tool upon the piece, which is rotated for the purpose," is shown in the engraving Fig. 1, and consists, as will be seen, of two pointed pieces A, A of wood serving as centers and each bound to a tree, and supporting the ends of the piece C to be turned, while on the opposite side of the tree is fixed in the same manner a straight piece of wood B, which acts as a rest for the chisel or other tool with which the turning or cutting is to be done. The power for rotating the piece C to be turned is obtained by attaching a cord D to a flexible limb of the tree, passing it one or more turns around the piece and forming in its lower end a loop for the foot of the operator, who rotates the piece towards himself by depressing the foot, bending down the limb by the movement, which, when he raises

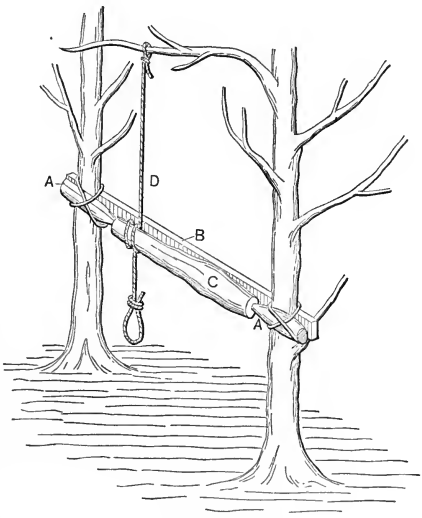


Fig. 1. — The Old Tree Lathe

his foot, returns to its original position, rotating the piece backwards in readiness for another pressure or downward stroke of the foot. The work was slow and laborious, yet from old samples of the pieces thus produced we may see that an extraordinary good quality of work could be done, particularly considering the primitive methods used.

We read that:

"Wood-turners in some of the Asiatic countries go into the deep forests with axes, and with a few rude turning tools and hair ropes build their lathes and turn out objects of beauty and grace, says the Wood Worker. Two trees are selected which stand the proper distance apart near a springy sapling. With his ax the turner cuts out his centers and drives them opposite each other into the trees, which serve as standards. From one tree to the other he places a stick of wood for a tool-rest. With his ax he trims the branches from the sapling, fastens his hair rope to the little tree, gives the rope a turn around one end of the block of wood he desires to turn into shape, and fastens the free end of the rope to a stick which he uses as a foot treadle. When he presses down on the treadle the wood he is turning revolves, and the spring of the sapling lifts the treadle so that it can be used again."

The next form of lathe to which these crude efforts seem to have led was one in which the flexible limb, though in another form, was used, but the device became very nearly a self-contained machine. A piece of wood formed a bed for the lathe and to this was fixed the blocks forming the centers, which have since become the head and tail stocks of the lathe. The machine appears to have been used in doors, as the flexible limb of the tree had been replaced by a flexible strip or pole, "fastened overhead" and called a "*lath*," from which circumstance some writers think that the name "*lathe*" was derived. The driving cord was still wound around the piece to be turned. No mention is made of the method of supporting the tool, but it is probable that a strip of wood was fastened to the "bed" for that purpose.

The next improvement in developing the lathe brings its form within the memory of the older mechanics and is shown in Fig. 2. In this case there is a rude form of head-stock B, and tail-stock E,

both constructed at first of wood, and the tail-stock continuing to be so constructed for many years. In this form of lathe the head spindle is first found, having in the earlier examples a plain "spool" around which the driving cord D was wound, and later on a cone pulley constructed as shown in Fig. 3, by which a faster speed was possible with the same movement of the foot. The lower end of the driving cord was fastened to a strip of wood F, the farther end of which was pivoted to the rear leg, in the later examples of the "spring-pole lathe," as it was then called, the bed having been mounted upon legs as shown.

The bed A, was formed of two pieces of timber set on edge and

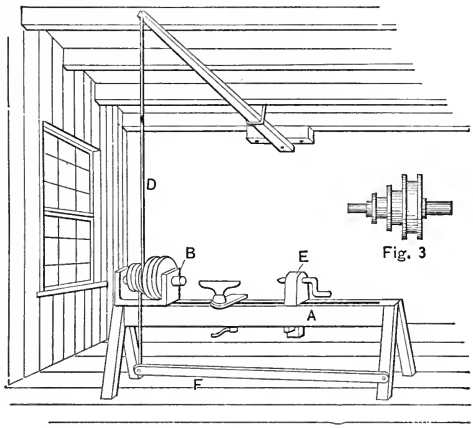


FIG. 2. — The "Spring-Pole" Lathe.

a short distance apart, properly secured at the ends. This afforded a space down through which passed a long tennon formed upon a wooden block answering for a tail-stock E. This was held in any desired position by a wooden key, passing through it under the bed.

What was the early form of rests for this lathe does not seem to be known, but somewhat later the rest was constructed of cast iron and very much as in an ordinary hand lathe of the pattern-maker or wood-turner of the present day, and as shown in Fig. 2.

This lathe was used for both wood and metal, the tools being held in the hand as the slide rest had not yet been invented, as will be seen later on in this chapter.

In the use of the spring pole and cord in connection with the

cone pulley, as shown in Fig. 3, some workman discovered, probably by turning a heavy piece, that its forward motion would continue when the foot was raised, provided the tool was withdrawn from contact with the work. It was but natural to make the cone pulley of heavier material, as of cast iron, or to weight it with pieces of iron or with lead plugs cast into it, and thus make it serve the office of a balance-wheel and so keep up the forward revolution of the work as long as it was given the proper impetus by the downward strokes of the foot.

Another style of lathe that was used mostly for small work, generally metal work, was called a "fiddle-bow lathe," on account of the method of driving it. In this lathe, which is shown in Fig. 4,

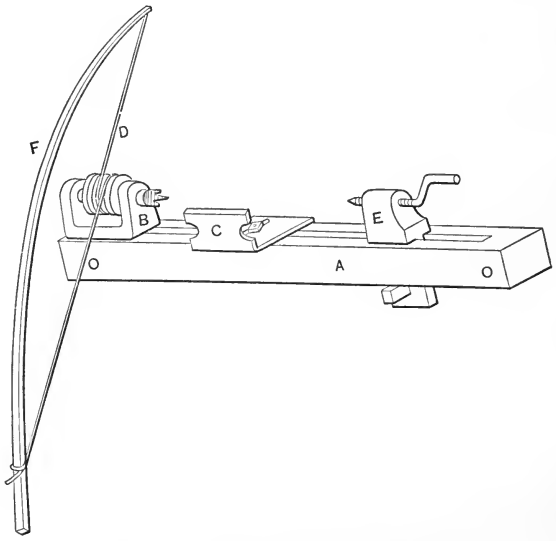


Fig. 4. — The "Fiddle-Bow" Lathe.

the same idea of propulsion is used as in the former examples, that of a cord passing around either the piece to be turned or a rotating part of the mechanism by which the piece was revolved. In this case, however, instead of the resistance of the flexible limb of a tree or of a "spring pole" acting to keep the driving cord taut, it is held in that condition by the flexible bow F, which is bent to the form shown by the driving cord D. The engraving is an exact reproduction of a lathe, the bed A of which was about twelve

inches long and it had a capacity of about two inches swing, that was made by an older brother for the use of the author when he was nine years old, and in the use of which he became quite a boyish expert in turning wood and metals. The head-stock B, and rest C, were formed of bent pieces of wrought iron, and the "spur center" was formed upon the main spindle, the point being used as a center for metal work.

Lathes driven in this manner are still in use by watchmakers and jewelers and a great deal of very fine hand work is performed with them.

The main features in all these lathes were, first, to suspend the work to be done, or the piece to be operated upon, between two fixed pivots or centers; second, to revolve it by means of a cord wrapped around it, or some part of the machine fixed to it, and kept tightly strained by means of some kind of a spring, as an elastic piece of wood; and third, to reduce the piece to be operated upon by means of a tool having a cutting edge which was held tightly against the material to be operated upon, thus reducing it to the circular form required; fourth, that to accomplish this it was necessary to revolve the piece to be operated upon, first *towards* the cutting tool for a certain number of revolutions, then by a reverse motion of the taut cord to reverse the circular motion, at the same time withdrawing the cutting-tool for an equal number of revolutions. By this method one half the time was lost, as no cutting could be done while the work was running backward.

It was later found that if the flexible pole or "lath" was rather weak and the piece of work to be operated upon was quite heavy, acting as a balance-wheel, its forward revolution was not wholly arrested, but only checked as the foot was raised, provided the cutting-tool was withdrawn from contact with the work a moment before the upward motion of the foot began.

By this it was seen that great advantages might be gained if the lathe could be made to not only revolve continuously in the direction of the tool, but also with the same force, whereby the tool might be kept in constant contact with the work.

Already the pulley, as applied to the spindle of the lathe, was known. The cord wrapped around it and used to rotate it was

known. Doubtless an assistant had furnished the power to drive the lathe while the mechanic handled the tools. What would be more natural than the arrangement of a large wheel, journaled to a suitable support at the front or rear of the lathe, and having the cord connected with it as a driver. And with this device and the problem of revolving it by hand, a handle set between its center and circumference would be natural also, and thus came the crank. We do know that somewhat later than this machines were driven in exactly this manner, the large wheel being constructed with a heavy rim and acting as a balance-wheel.

At this stage of development the large driving-wheel was rather an attachment than a part of the machine itself, and doubtless so remained for a considerable time. The next change was to locate it beneath the lathe bed, directly under the head-stock, and instead of the use of the handle forming practically a crank of long leverage it was constructed as it is in the sewing-machines of the present day; that is, the wheel journaled upon a fixed stud and the previous long handle reduced to a wrist-pin for the attachment of a connecting rod, or in the older phrase a "pitman," which term was given to one of the men handling the vertical saw used in sawing up logs into timber and planks in the olden times (and even now in oriental countries), wherein the log was supported over a trench or pit, the upper end of the saw being handled by the "topman" and the lower end by the "pitman" or man in the pit. When these saws were later on mounted in a rectangular frame or "gate" having a vertical, reciprocating movement and operated from a crank-shaft by a connecting rod from the one to the other, this rod took the name of the former man who performed this office, hence the term "pitman."

The location of this pitman or connecting rod, as has been said, was directly under the head-stock and well within the convenient reach of the operator when attached to a suitable "treadle" whose rear end was pivoted to the back of the machine and whose front end formed a resting-place for the operator's foot. This arrangement answered very well and was useful when the work of the lathe was near the head-stock, but was not adapted to long work, to accomplish which the operator would need to stand near the tail-stock or even midway between that and the head-stock. To remedy this defect

a strip of wood was hinged to the front leg of the lathe at the tail-stock end and its opposite end to the front end of the treadle. This was of considerable use, its principal drawback being that while at the treadle end its vertical movement was the same as the latter, this movement was gradually lessened until at the tail-stock end of the lathe it was nothing. Hence, much more power was required to drive the lathe at its center than at the head-stock, and this was rapidly increased as the work was nearer the tail-stock end of the lathe.

To remedy this defect the large driving-wheel was mounted upon and fixed to a revolving shaft upon which was formed two cranks, one near the wheel and the other at the tail-stock end of the lathe. This shaft was properly journaled in boxes formed upon or attached to cross-bars fixed to the legs at each end of the lathe. From these cranks hung two connecting rods whose lower ends were pivoted to two levers pivoted to the rear side of the lathe, and whose front ends were connected by a wooden strip or "foot-board." The length of these levers was such that the movement of the foot-board was about twice the "throw" of the cranks, so that with a foot movement of twelve inches the two cranks were about three inches, center of shaft to center of connecting rod bearing.

This was then and for many years the prevailing form of foot lathes and was quite extensively used, not only for turning wood but for iron, steel, and other metals as well.

There were many of the older mechanics who would work the entire day through. At that time a day's work was not eight, nine, or ten hours, but "from sun to sun," or from daylight till sunset, day after day, treading one of these foot lathes and turning out a much larger quantity of work than these crude facilities would seem to render possible.

In Fig. 5 is shown this form of foot lathe that was in use for many years for turning both wood and metals. The illustration is a drawing of a lathe built by the author when he was between fifteen and sixteen years of age. The bed A, legs B, the cross-bars C, C, the back brace D, and treadle parts E, F, were built of wood, as was also the tail-block G, which was of the form shown in Fig. 4, except that beneath the screw forming the tail center was a wooden

key *g*, for keeping this screw always tight, as there was a tendency, from strain and vibration, for the screw to work loose.

The tool-rest was of the usual form, except that instead of a wedge, in connection with the binder H, to hold it in position, or the use of a wrench on the holding-down bolt, an eccentric of hard wood with a handle formed upon it, as shown at J, was used. This was the first occasion where the author saw an eccentric used for a similar purpose. It worked so well that he fitted similar eccentrics to the stops of the three windows in his little workshop to hold the sashes in any desired position when they were raised, and by

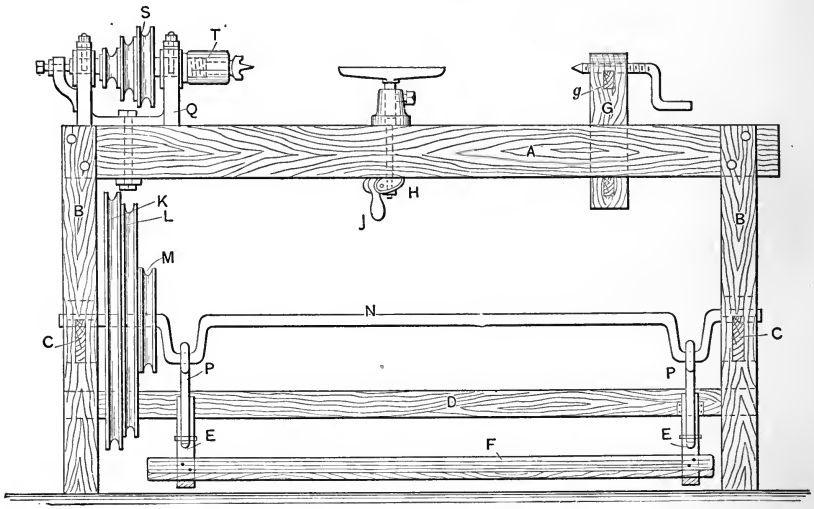


Fig. 5. — Foot Lathe for Turning Wood or Metals.

a turn in the opposite direction to secure them when they were closed.

The large wheel was of cast iron, rescued from a scrap heap, and had only the grooves for the two faster speeds K, L, the part M being made of wood and fastened to the arms of the wheel. A friendly blacksmith forged the cranks in the shaft N, and the eyes in the lower ends and *hooks* in the upper ends of the connecting rods P, P. These were first made of wood similar to the connecting rods on a sewing-machine with a closed bearing at the top, but the tendency to pinch one's toes under the treadle when they happened to be accidentally placed in this dangerous position soon

led to the iron connecting rods with the hooked ends whereby the worst that could happen was the connecting rods becoming *unhooked.* The shaft N rested in wooden boxes, the lower half being formed in the cross-bars C, C, and a wooden cap held down by two wood screws forming the top half. The bearings of the shaft and the cranks were filed as nearly round as they could be made by hand with the means and ability available.

The pattern for the head-stock was made as shown in side elevation in Fig. 5, with the housings for the spindle boxes as shown in Fig. 6. The boxes were made in halves, of babbitt metal and cast in place in the head-stock in this manner. The head spindle was located in place and held by a thin piece of wood clamped on the inside and outside of the housing and having semicircular notches in their upper edges and a slight recess on their inner sides so as to provide for making the box slightly thicker than the housing.

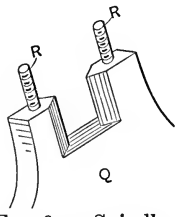


FIG. 6. — Spindle-Box Housings.

The lower halves of the boxes, having been cast slightly higher than the center of the spindle bearings, were removed and filed down to the proper level and then replaced, the spindle again laid in, the strips of wood clamped on in an inverted position and the top half of the box cast. This part projected slightly above the top of the iron casting and was held down by an iron cap having two holes drilled in it which fitted on the threaded studs R, R, which had been cast into the head-stock for this purpose. The spindle had been turned up in an old-style chain-feed lathe, of which more will be said later on. The cone pulley S was of cherry, simply driven on tightly and turned up to the form shown.

The front end of the spindles was threaded but not bored out. Upon this thread was cast a babbitt metal bushing T, having a *square* hole in its front end, which was formed as follows: With the spindle in its place a wooden mold of proper form was placed around it and, while it fitted the collar on the spindle at one end, was open at its front end. A tapering, square piece of iron of proper dimensions to form the square hole was placed with its small end against the nose of the spindle and held in that position

by the tail screw. The opening around it was closed by a piece of wood of proper form and the job was "poured," and the bushing afterwards turned up with a hand tool. Into this square hole could be fitted proper centers for turning wood or metal, and by removing the babbitt metal collar a face-plate could be put on for face-plate work.

It will be noticed that the lathe had been arranged for two speeds proper for turning wood and the softer metals, and one speed considerably slower for iron. A piece of belting was provided which could be easily removed to shorten the belt the proper amount for this purpose.

The lathe would swing eight inches and take in between centers four feet. It was found that the round belt did not give sufficient driving power and a new spindle cone of only two steps was put on, the iron balance-wheel lagged up for a flat belt, and the pulley M turned down for the same purpose. This permitted the use of a belt an inch and three-quarters wide, and as no regular belting was available when the job was done an old trace from a harness suffering from general debility was ripped open and a single thickness of the leather soaked up in water, dried out, treated with neat's-foot oil and used with such good results that it was never replaced.

To this lathe was fitted a small circular saw provided with an adjustable, tilting table upon which not only wood but sheet brass could be cut. Another attachment was a small jig-saw that would cut off wood up to half an inch thick.

One of the disadvantages of the usual form of foot-power lathe was the short connecting rod or pitman which thereby formed too great an angle to the center line from the wheel center to the point of attachment to the treadle, thereby increasing the friction and decreasing the useful effect of the foot-power. It was apparently to avoid this condition that a somewhat peculiar form of lathe was devised and built in the railroad shops at Plattsburgh, N. Y., about 1860, and which is shown in end elevation in Fig. 7. This was an engine lathe of about fourteen-inch swing, built with cast iron bed A, legs B, and all the parts of metal that are now so constructed. Instead of placing the large driving or balance wheel beneath the lathe bed as formerly, the lathe was belted from a

cone pulley of three steps on an overhead countershaft C, provided with the usual hangers D. This countershaft was of a length equal to the length of the lathe and had fixed at the end over the head of the lathe a heavy wheel E, into the hub of which was fixed a stud or wrist-pin F, while on the opposite end of the countershaft was fixed a disc for carrying a similar stud. These formed two cranks to which were fitted long connecting rods G, the lower ends of which were pivoted to the treadles H, whose rear ends were pivoted to the legs B, as at J. The treadles H are located outside of the legs B, and connected by the foot-board K. The weight of the connecting rods G, the treadles H, and the foot-board K are balanced by the proper counterbalance added to the fly-wheel E, as shown. The author knows from personal observation that this lathe would run very steadily and with a good deal of power, and that its general performance was much better than foot lathes of the usual type. Doubtless the momentum of the balance-wheel, cone pulley, and countershaft was very beneficial in maintaining an equable speed under varying conditions of resistance from the operation of cutting-tools and the like, while the cast iron cone pulley on the main spindle did some service in the same direction.

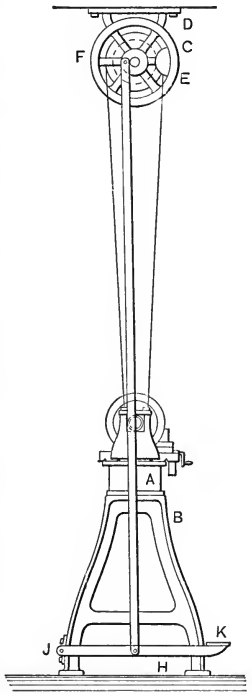


FIG. 7. — Foot Lathe, Driven from a Countershaft.

The only disadvantage in this lathe was that it required too long a time to get it up to its regular speed and necessarily too much time was consumed in stopping it, as there was no provision for disconnecting the main spindle from the driving-cone by a clutch mechanism or similar device, as is frequently the case with special forms of the lathes of recent design.

There has been manufactured for some years a special type of friction clutch that is very useful in driving foot-power machinery. It consists essentially of a drum mounted upon and

loosely revolving around the shaft to be driven, and having a friction, clutch mechanism contained within it and so operating that the drum will turn freely in one direction but the moment it is revolved in the opposite direction the friction device comes into operation, the drum is firmly clamped to the shaft, which is thus caused to rotate with it. To this drum is attached one end of a flat leather belt, which is wrapped around it several times and its free end attached to the movable end of a treadle, which is usually hinged at the front instead of the back of the machine. In operation the pressure of the foot acting on the drum by means of the belt rotates it in the forward direction, which causes its friction mechanism to act and revolve the shaft through as many revolutions as there are convolutions of the flat belt around the drum. The rotary motion thus set up is continued by the momentum of a balance-wheel, and as the foot is raised the treadle is caused to follow it, either by the action of a spring similar to a clock spring within the revolving drum, or a spiral spring acting upon another strap, also wrapped around the drum, but in the opposite direction to the one attached to the treadle. By this device several revolutions of the driving-shaft could be produced at each depression of the foot, the treadle frequently passing through an arc of thirty to forty degrees.

This device was particularly applicable to the driving of light foot-power machinery which it did very successfully, and as the strokes of the foot need not be of the same length and were not confined to any certain cadence it was not nearly as fatiguing as the crank device in which the strokes of the foot were always the same distance and with the same speed.

In the above described device, however, the balance-wheel was more necessary and it was also necessary that it should be so arranged as to revolve with a much higher rate of speed than the large wheel of the older form of foot lathe. There was one advantage in this condition, however, that in consequence of its higher speed the balance-wheel could be made of much smaller diameter and consequently much lighter in weight, and therefore occupying much less space under the machine.

CHAPTER II

THE DEVELOPMENT OF THE LATHE SINCE THE INTRODUCTION OF SCREW THREADS

Origin of the screw thread. Ancient boring tools. Suggestions of the screw form. The "Worm Gimlet." Making the first nuts. An old device for cutting threads in wood. Archimedes and his helical device for raising water. Jacques Berson's French lathe. Joseph Moxan's English lathes. The French lathe of 1772. John Maudsley's English lathes. Maudsley's slide-rest. Another French lathe. The use of a "master screw." A form of slide-rest. An old-time worm and worm-gear. Simple method of developing the screw thread. Anthon Robinson's triple-threaded screw. The many uses of the early lathes. An old "chain lathe." Its detailed construction. Cutting left-hand threads. Crown gear and "lantern pinion" for operating the lead screw. Transition from wooden to iron lathe beds. The Putman lathe of 1836. The Freeland lathe of 1853. Various classes of lathes to be illustrated and described.

THE origin of the screw thread, or the threaded screw, reaches so far back into ancient times that it is impossible to determine when, where, or by whom it was first conceived or used. That it was known in one form or another as far back as the use of iron for tools is altogether probable. Holes must have been made in wood by some kind of an iron instrument which was the predecessor of the gimlet. This instrument was most likely square or of some form nearly approaching that. In order to be at all effective it must have had sharp corners.

As the straight-edged sharp knife was first accidentally and then purposely hacked into notches and became the first saw, so may the corners of the early boring instruments have had notches formed in them to facilitate their action upon the material to be bored. These notches may have been gradually deepened for the same purpose, with the idea that the deeper they were the more useful they would become. We can very readily conceive that

in making these notches the tool was laid on its side and gradually revolved as the notches were made, beginning at the point and working upwards as the tool was revolved. This of itself would have a natural tendency to produce a semblance of a screw thread, which would increase the efficiency of the tool by drawing it into the wood to be bored. When this tendency was noticed it was also natural to see why it acted in this manner and to increase this action by more carefully making these notches. In time the "worm gimlet" was undoubtedly evolved.

The form of a screw thread having once been arrived at, the realization of its usefulness for various purposes was only a question of time. It is altogether probable, however, that for the purpose of holding parts of a machine together, or for similar mechanical purpose, screws were first made of wood. It is also pretty certain that they were first made in a very crude form without much regard to the exactness of the pitch or form of the thread, although the V-thread would be the most natural because the most simple form. It is also generally conceded, of course, that they were made by hand and probably with the rude knives then used, as hand tools were the only ones in use.

As to the methods used in making the first nuts for use with the screws, it is probable that they were quite thin as compared with the pitch of the thread, possibly containing but two or three complete revolutions of the thread, which was worked out by sharp-pointed instruments, as the point of the knife or by similar means. This method may have led to the insertion of a metal tooth in a wooden screw and the cutting of the thread in the nut in this manner. We do know for a certainty that a somewhat similar means was used many years later, as the author saw a device such as is represented in Fig. 8, which was preserved as a curiosity, representing the early mechanical method of doing this work.

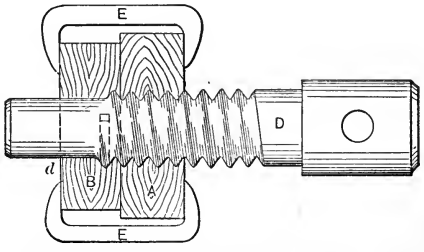


FIG. 8. — Screw Threading or Tapping Device for Wood.

This device consisted of a turned and threaded screw D, of

very hard wood, having one end turned down to a diameter equal to that at the bottom of the thread, while the opposite end was made much larger and contained a hole for passing a bar or lever by means of which it was rotated. At the termination of the thread and beginning of the smaller straight portion the thread was cut away, leaving an abrupt termination, and at this point was inserted a tooth of steel formed in a rough manner to the shape of the thread.

In a wooden nut A a thread had already been cut, by some manner unknown, and through this the screw D was fitted. The piece B, to be tapped or threaded, was clamped to this by means of the steel clamps E, E, binding the two firmly together. To all appearances the tooth or cutter *d* could be set in or out so as to cut merely a trace of the thread the first time through, then another deeper cut, and finally finished to the full depth. The author had no means of ascertaining the origin of the device, but the wood of which it was composed was black with age and the man who possessed it could not tell how many years his father had owned it or where he got it. It was certain, however, that both of them had been mechanics who had made and repaired the old-time wooden spinning-wheels in which a wooden screw about one inch in diameter had been used for tightening the round band by which the twisting mechanism was operated.

Archimedes, the most celebrated of the ancient mathematicians, certainly had a good idea of the screw thread, as is shown in his famous screw made of a pipe wound helically around a rotating cylinder with which he raised water fully two hundred years before the Christian era. Still it was doubtless a long time after this period before the screw was constructed so as to be applicable to the uses of the present day. Of the progress and development of this and other similar mechanical matters in these early times we have little authentic information. The development of such simple machines as the lathe preceded much that was mechanically important, and to its influence we owe a great deal of the early advancement in the mechanic arts.

We know that a Frenchman by the name of Jacques Berson, in 1569, built a lathe that seems to have been capable of cutting threads on wood. An engraving of his lathe is given in Fig. 9.

As will be seen in this engraving it was a large, clumsy and cumbersome affair, considering the work it was designed to perform. While the various parts of the machine are not very clearly shown, enough is given to show us that he had a wooden lead screw to give the pitch of the thread by means of a half nut which appears to have been fixed in a wooden frame, to which in turn the piece to be threaded was attached by being journaled or pivoted upon it. The lead screw and the piece to be threaded were both revolved by means of cords wound around spools or drums upon a shaft overhead, and held taut by weights instead of the flexible spring pole already described. These cords were fastened to a

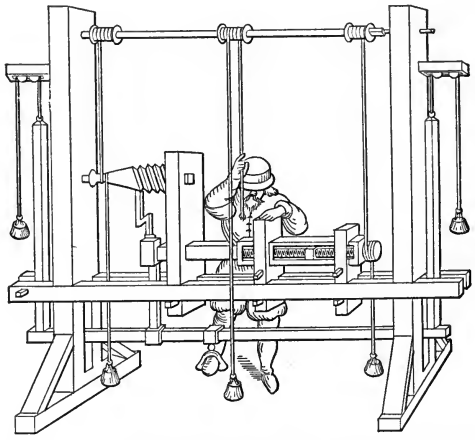


Fig. 9. — Berson's French Lathe, built in 1569.

vertically sliding frame, also balanced by cords and weights, and to which was attached a sort of stirrup adapted to the foot, by which the machine was operated.

Considering the early time at which this lathe was constructed, it shows a good deal of ingenuity and may well have been the forerunner of the developments in this line which came after it.

It is a matter of record that in 1680 a mechanic by the name of Joseph Moxan built lathes in England and sold them to other mechanics, but we do not possess any certain or authentic knowledge of their design, as to whether or not screw threads could be cut with them or whether they were designed for work on wood or metals, or both. In all probability they were foot lathes and

used on all materials that had been formed in a lathe up to that time.

In the year 1772 the French encyclopedia contained the illustration of a lathe which was provided with a crude arrangement of a tool block or device for holding a lathe tool and adapting it to travel in line with the lathe centers. By this it would seem that the inventor had some idea of the slide rest as it was known at a later day by its invention in a practical form by John Maudsley in England, in the year 1794. Whether Maudsley had seen or heard of the invention shown in the French encyclopedia or not, it would seem fair to assume that he must have seen that or something akin to it, as the twenty-two years elapsing between the one date and the other must have served to make the earlier invention comparatively well known in the two nearby countries, both of which contained, even at this early day, many mechanics. It is interesting to observe that the slide rest invented by Maudsley over a hundred years ago has been so little changed by all the improvements since made in this class of machinery.

There seems to have been an early rivalry between the French and English mechanics in the development of machines and methods for advancing the mechanic arts. The next development of the screw-cutting idea seems to have been of French origin. In this lathe there was an arbor upon which threads of different pitches had been cut. These threads were on short sections of the arbor and by its use the different pitches required could be cut. While the exact manner of using this arbor was not described, its probable method of use will readily suggest itself to the mechanic, and was, no doubt, used at an earlier period, and in fact was what led up to the use of a lead screw or arbor with a multiplicity of different pitches. The principle is analogous to that used in the "Fox" brass finishing lathe so well known and extensively used, not only in finishing plain surfaces but in "chasing threads."

This machine is shown in Fig. 10, which is a perspective view giving all the essential parts of the mechanism. The head-stock A and tail-stock B are of the usual form in use at the period, and were mounted upon the wooden bed C in the usual manner. The piece D to be threaded, and an equal length of lead screw or "master screw," as it was then called, were placed end to end in the lathe,

the outer ends held in the lathe centers, and their inner ends, evidently fixed to each other by a clutch of some kind, were supported by a kind of center rest F. Fixed to the front of the bed C was a cast iron supporting bar G, of T-shaped section, extending nearly the entire length of the lathe bed. Upon the bar G, the top of which was of dovetail form, was fitted the carriage H, which was adapted to slide upon it and to support a thread-cutting tool J, and a tool or "leader" K, which fitted into the thread of the "master screw" E, and served the same purpose as the lead screw nut of the present day. Evidently the operation was that by revolving the piece D the "master screw" E was also rotated, and this rotation of the

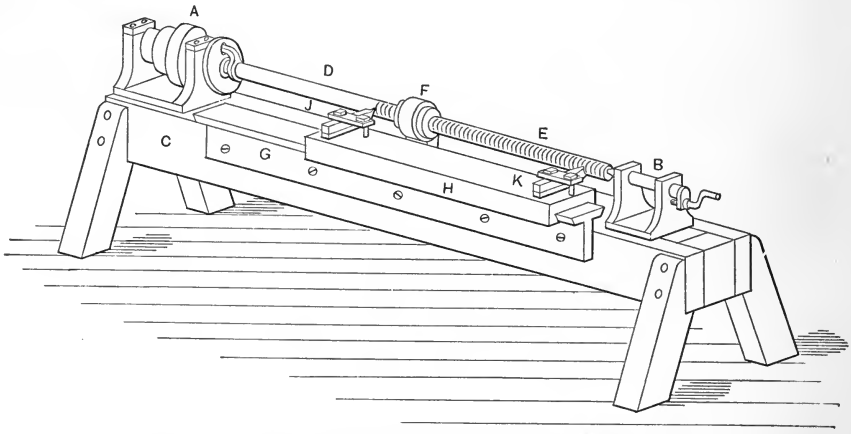


Fig. 10. — Thread-Cutting Machine using a "Master Screw."

threaded screw, acting upon the "leader" K, forced the carriage H forward, causing the thread-cutting tool J to cut a thread upon the piece D, of a pitch equal to that upon the "master screw" E. It is probable that no better means of adjusting the thread-cutting tool J was provided than setting it in by light blows of the hammer. While the threads thus cut were probably rather poor specimens of mechanical work, they answered the requirements of the times, and as usual better means were devised for making them as the need of better and more accurate work created new demands and a higher standard of workmanship.

As will be seen in the above example the idea of the slide-rest is used. In this case some such device was a necessity. Doubtless

threads had been cut with some sort of a "chaser," or tool with notches shaped to the form and pitch of the thread. These were very extensively used later and for many years in brass work, and the old-time machinist was very expert in their use. The slide-rest, as we know it, while it relieved the workman from the fatigue of holding the tool firmly in his hands and depending entirely upon them for the position of the tool, with the exception of such *support* as the fixed rest gave him, was comparatively slow in coming into general use. While its usefulness must have been apparent to the average mechanic, the conservative ideas then in vogue must have retarded its prompt adoption, as they did many other meretorious inventions.

By the use of the device shown in Fig, 10, it is plain that a different "master screw" was needed for each different pitch of thread to be cut, although the diameter of the work might be anything within the range of the lathe to hold and drive, so that provision was made for supporting the inner ends of the piece to be cut and the "master screw," and for driving the latter by the former. The idea of driving the "master screw" or lead screw at a different speed from that of the piece to be threaded had not yet been thought of, and it was years before this development took place.

But before proceeding to this phase of the development of thread cutting, and consequently with the further development of the lathe, let us look a little farther into the methods of generating threads. That is, of producing the "master screw," from which other screws might be made.

The author well remembers during his boyhood an old curiosity shop out in the country in which various kinds of hand machines were made and repaired. Among other things made were various appliances and devices for spinning woolen yarn and reeling it up into skeins of forty threads to a "knot," as it was called. To furnish an automatic counter for this reel a worm-gear of forty teeth was used which engaged with a single threaded worm on the reel-shaft. Both the shaft having the worm formed upon it and the worm-wheel were of wood, usually oak or maple, and the thread was formed by wrapping a piece of paper around the turned shaft and cutting through this with a knife so as to

make its length equal to the circumference of the shaft, its width representing the longitudinal distance on the shaft. This piece of paper was then divided into equal parts at each end and inclined lines drawn upon it as shown in Fig. 11, the divisions being equal to the pitch of the thread, found by spacing the circumference of the worm-gear blank for the forty teeth. The paper was then glued around the shaft and the diagonal lines gave the correct development of the screw thread, which was worked out with a fine saw, a chisel, or knife, and a triangular file. The teeth of the worm-gear were similarly cut to the proper V-shape, and the result was a perfectly practical and really workmanlike piece of mechanism that answered the purpose remarkably well.

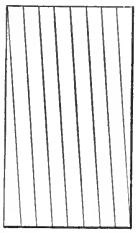


FIG. 11.—Thread Developed on Paper.

This same method of laying off screw threads was in practical use many years ago and was used by one Anthony Robinson in England as early as the year 1783, at which time it is recorded of him that he made a triple-threaded screw 6 inches in diameter and 7 feet 6 inches in length. It is said that he first laid off one thread by the method above described, leaving a sufficient space between the convolutions for the other two threads. This first thread was then worked out by hand with the time-honored hammer, chisel, and file, and he afterwards used this thread as a guide for making the other two by the same primitive means.

In the light of the present facilities for cutting threads this process seems most tedious and laborious, and yet much of the machinist's work of that time was equally slow and must have sorely taxed the patience of the workman, whose principal and often only machine was a lathe of very crude design and workmanship, and in which he managed to do not only turning and boring but slotting, splining, milling, gear-cutting, and an endless variety of similar jobs, and in lieu of a planer having recourse to his ever ready cold chisel, hammer, and file, which with a straight-edge enabled him to make many a flat surface of remarkable nicety considering his limited facilities. And from these pioneer machinist's came the American machinist of to-day, the most thorough, best educated and expert mechanic the world has ever seen.

It will doubtless have been noticed that in the earlier examples of the lathe, as in most of the machines in use, the framework of the machine in the lathe, the bed, and legs, were made of wood with the various metal parts secured to them. A good example of this method of construction, as well as the general construction of the lathes of the date when this one was built, is shown in front end elevation in Fig. 12, and in front elevation in Fig. 13. The history of this lathe is well known to the author, who was well acquainted with the old Scotchman, one John Rea, who had a small machine shop, wood shop, iron foundry, and sawmill in East Beekmantown, Clinton County, New York State, during and for many years prior to the civil war.

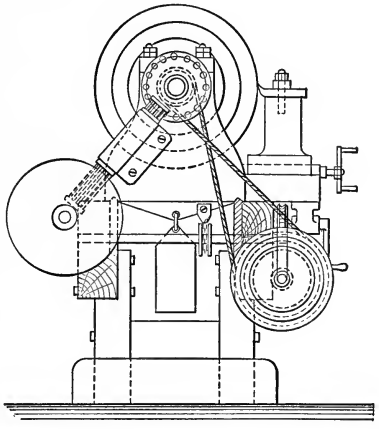


FIG. 12. — End Elevation of "Chain Lathe."

This lathe had, as will be seen by an inspection of the drawings, a bed composed of two timbers, placed at the proper distance apart and supported upon wooden legs, which in turn rested upon a cross timber supported by the floor. The timbers were of hard maple, those forming the bed being about 5 inches thick and 12 inches deep and were about 15 feet long. The lathe would swing about 32 inches over the bed. The patterns were made by Mr. Rea, the castings made in his foundry, and the machine work done in the nearby village of Plattsburgh.

The "ways" or V's of the lathe were of wrought iron about $\frac{5}{8}$ x 3 inches let into a "rabbit" cut on the inside edges of the timbers forming the bed, and fastened by large wood screws. The top edges of these iron strips were chipped and filed to an angle of about 45 degrees to the sides, thus making the V an angle of about 90 degrees. The head-stock had cast in it square pockets in which the boxes for the main spindle were fitted by filing, and were held down by a rough wrought iron cap through which passed two threaded iron studs which had been cast into the metal. Upon

these were two nuts as shown. The main spindle was of wrought iron and carried a wooden cone pulley built up on cast iron flanges keyed to the spindle. There were no back gears.

The carriage was of the roughest description and had a hand cross feed for the tool block, which carried the old-fashioned tool-clamping device held in place by studs and nuts. The longitudinal hand feed was by means of a crank-shaft and pinion with cast teeth and a rack similarly formed, fastened to the front of the bed by wood screws. The longitudinal power feed was by means of an ordinary iron chain (hence the common name of "chain lathe" given to a lathe having this method of feeding). This chain ran over a very clumsy form of sprocket-wheel made somewhat similar to those used in chain hoists of the present day. At the head end of the lathe this sprocket-wheel was fixed upon a shaft which carried on its front end a very crude form of a worm-wheel arranged to engage with an equally crude worm upon a shaft journaled in boxes at the front of the bed, one of which was pivoted to the front of the bed and the other capable of sliding vertically and therefore making provision for dropping this worm out of contact with the worm-gear when it was desired to "throw out the feed." To keep this feeding mechanism in gear a

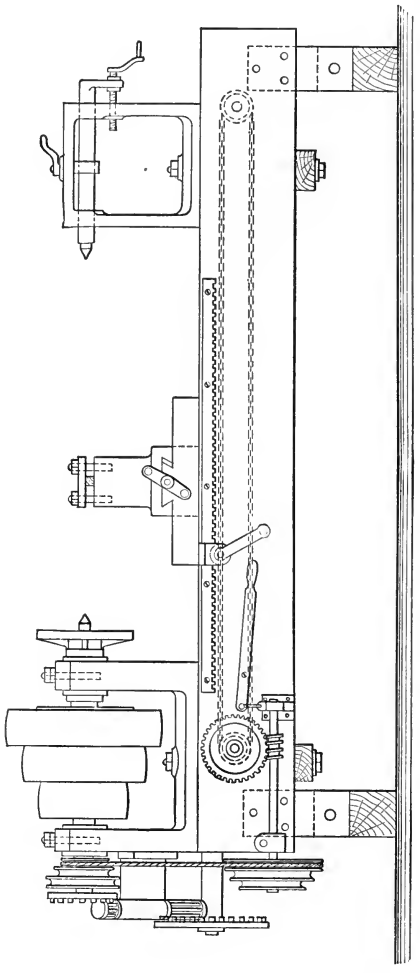


Fig. 13. — Front Elevation of Old "Chain Lathe."

lever was pivoted upon the front side of the lathe bed, one end connected with the sliding box of the worm-gear shaft and the other hooked under a pin driven into the front of the lathe bed, as shown in the engraving.

This worm-shaft was driven by a round leather belt working in one of the grooves of a three-step cone pulley fixed upon it, and extending up to a similar three-step cone pulley fixed upon the rear end of the main spindle. These pulleys were of hard wood and attached to cast iron flanges fixed in place. The belt was a "home-made" production but very much resembling the best twisted round leather belts of the present day, and was about three quarters of an inch in diameter.

The belt on the cone pulley upon the main spindle was about three and a half inches wide, the large step on the cone being about twenty inches in diameter.

It will be noticed that no provisions was made in this lathe for cutting left-hand threads. It seems altogether probable that the use of left-hand threads began many years after right-hand threads were developed and used, as the need of them no doubt did not exist until the mechanical arts were much farther advanced and possibly not until they were wanted for producing a contrary motion in devices using the worm and worm gear.

The tail-stock was of very simple construction, as will be seen in the engraving, the tail spindle having formed upon its rear end a downwardly projecting arm which embraced a screw tapped into the main casting and being provided with a crank by which it was operated. To bind the spindle in any desired position a ring was provided, through which the tail spindle passed, and to which was welded a bolt end passing up through the casting and being provided with a lever nut as shown. It will be noticed that by this construction the operation of binding or clamping the tail spindle tended to raise it out of its true bearing position and hold it suspended by this binder and its contact with the top surfaces of the holes through which it passed in the main casting. This continued to be the practice for clamping a tail spindle for many years before the present method of splitting the bearing at the front and fastening it by a clamping screw was first used.

The lead screw was placed at the back of the lathe and had

fitted upon it a curved forging, carrying a solid nut and capable of being attached to the carriage by two bolts when it was desired to cut threads. This forging was frequently called a "goose neck," from its peculiar curved shape. The thread of the lead screws was square and four threads to the inch. It was, of course, made of wrought iron, the use of steel for this purpose being of much later date.

The method of driving the lead screws was characteristic and peculiar and is one of the main reasons for introducing this lathe to the attention of the readers of this book, as it marks one of the first known methods of changing the ratio of speed between the main spindle and the lead screw by means of gears of a varying number of teeth, which is here done in a very crude but comparatively effective manner. This method was as follows: Upon the rear end of the main spindle was fixed a flange having in its face a series of pins which formed the teeth of a "crown gear" and which engaged with a "lantern pinion" fixed upon an inclined shaft journaled in a bracket fixed to the lathe head and lining with the lead screw. This lantern pinion was made of two heads fitted upon the shaft and having pins running through the heads in a line parallel with the axis of the shaft, similar to the method seen in a brass clock.

Upon the lead screw was a crown wheel similar to that upon the rear end of the main spindle, and whose pins, or teeth, engaged with those formed by the pins or rods in the lantern pinion upon the lower end of the inclined shaft. The fact that this lantern pinion was of much greater length than that on the upper end would seem to indicate that the designer or builder of the lathe had intended to use different sized wheels on the end of the lead screw for the purpose of producing different ratios between the speed of the lead screw and that of the main spindle, and therefore to cut threads of differing pitches. This seems to have been the earliest method of producing this result by a change of gearing, and probably antedated the method of using differing diameters of spur gears, as it is well known that the crown wheel or pin gear and lantern pinion were the oldest form of gearing, and in use in Egypt at a very early date, and that an imitation of our spur gear was made in a similar manner by inserting the pins in the periphery

of the wheel instead of its face. The builder of the lathe in question probably borrowed his idea from some lathes very much older and which he had seen in his native country, as regular spur gearing for the same purpose had been used at a considerably earlier date than the building of his lathe, and as he was a man past middle life at that time. The lathe was built about 1830 and was in active service as late as 1875, although the lantern pinions and pin gears had been discarded and hung up on the walls of the old shop, and in their place were the usual spur gears, and a stud plate had been added for the purpose of carrying an idle gear so as to accommodate

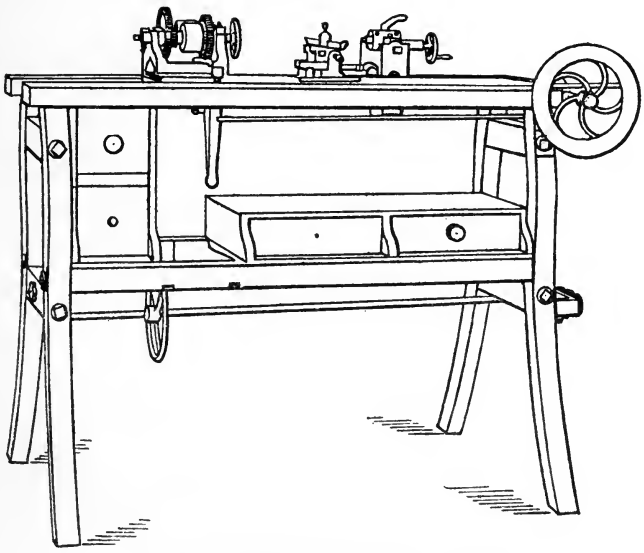


FIG. 14. — Putnam Lathe built in 1836.

different sizes of change gears, and a second idler when left-hand threads were to be cut. Otherwise the old lathe remained as it was originally built.

The transition from wooden to iron beds and legs for lathes was probably made by the early builders of these machines about 1840 or a few years later. It is certain that in 1850 lathes with iron beds were made in New Haven, Conn., and that from this time on iron was universally used for this purpose.

A good example of these lathes built about the time of the change from wood to iron beds is furnished in Fig. 14, of one of

the lathes built by J. & S. W. Putnam, in Fitchburg, Mass., about the year 1836, or somewhat earlier, and shows in a remarkably sharp contrast with those of the present day when all possible devices are adopted for powerful drives, rapid change gear devices for both feeding and for thread cutting, to the common inch standard and those measured by the metric system; with micrometer gages and stops; with turrets located upon the bed or upon the carriage; and with all manner of attachments and accessories for doing a great and almost endless variety of extremely accurate work, as well as for turning out an immense quantity of it.

One other example of the early lathes is shown that was in some respect somewhat ahead of its time, as will be pointed out. It is a 20-inch swing lathe built by A. M. Freeland, in New York City, in 1853. It is shown in Fig. 15. It is said that Mr. Freeland

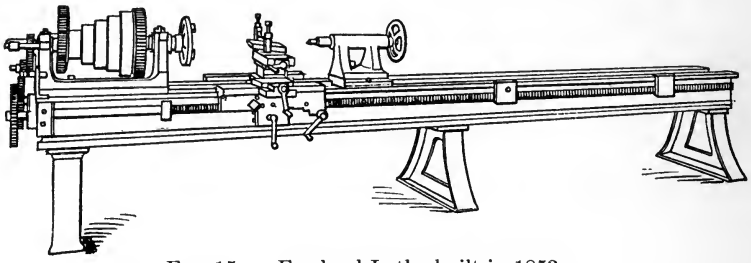


FIG. 15. — Freeland Lathe built in 1853.

used English machines as his models and was an admirer of Whitworth and his ideals of what machine tools should be. In this lathe the flat-top bed is used as in many English and some very good American lathes at the present time. It will be noticed that the apron is in a somewhat abbreviated form, only sufficient to support its very simple operative mechanism.

The carriage carried a cross-slide upon which were two tool-posts, one in front and one in the rear, which were connected by a right and left cross-feed screw, while there was a short supplemental screw for adjusting the back tool independently of the front one, and also a longitudinal screw for adjusting the tool lengthwise of the work being turned, so that the second or back tool would cut a portion of the feed, as the roughing cut and the front one take the remainder. It will be understood that the back tool is used upside down as in the modern lathes carrying the second tool.

There was no rack and pinion arrangement for lateral hand feed for the carriage, the lead screw being used for this purpose by engaging with its thread a pinion fixed to the shaft operated by the crank at the right-hand end of the apron.

It will be noticed that the driving-cone on the spindle has five steps, as in a modern lathe. The bed seems so light that it would now be called frail, in view of the present duty expected of a lathe of this swing, and in sharp contrast with the massive beds now used.

In future chapters will be shown the modern American lathes with all their peculiar features illustrated, explained, and commented upon as this work progresses, taking up, not only the regular types of engine lathes, but also those of a more special nature such as turret lathes, pattern lathes, bench lathes, high-speed lathes, gap lathes, forming lathes, precision lathes, multiple spindle lathes, and so on, including lathes driven with belts from a countershaft in the usual manner, and also those driven by electric motors with the most modern appliances.

In illustrating and describing these lathes much care has been exercised to have both the illustration and the description correct as to the facts shown and commented upon, and to this end the builders themselves have furnished the necessary facts so that the statements herein given are from proper authority and may be relied upon in considering the proper selection of the lathe best suited for the work for which it is to be purchased.

CHAPTER III

CLASSIFICATION OF LATHES

The essential elements of a lathe. The bed. The head-stock. The tail-stock. The carriage. The apron. The turning and supporting rests. The countershaft. Taper attachments. Change-gears. Classification applied to materials, labor accounts, and the handling of parts in the manufacture of lathes. The four general classes of lathes. The eighteen sub-divisions of these classes. The first class: hand lathes, polishing lathes, pattern lathes, spinning lathes and chucking lathes. The second class: engine lathes without thread-cutting mechanism, Fox brass lathes, forge lathes, and roughing lathes. The third class: complete engine lathes with thread-cutting mechanism, precision lathes, rapid reduction lathes, and gap lathes. The fourth class: forming lathes, pulley lathes, shafting lathes, turret lathes and multiple spindle lathes. Rapid change gear devices. Bancroft and Sellers device. The Norton device. Lathe bed supports. The precision lathe. The rapid production lathe. The gap lathe. Special lathes. Forming lathes. Pulley lathes. Shafting lathes. Turret lathes. Screw machines. Multiple spindle lathes. Variety of special lathes.

In considering what are the essential elements of a lathe they may be briefly stated, if we assume that in a simple lathe the work is to be what was originally intended, that is, held on centers, and may be stated in these terms, viz. The essential elements of a simple metal turning lathe are: suitable means for supporting and holding the work upon centers; proper mechanism for rotating the work; and a cutting-tool properly held and supported upon a traveling device actuated by suitable mechanism.

The first of these essentials comprise the bed, head-stock, and tail-stock, with their proper parts and appendages, so far as the fixed parts and centers are concerned, and including legs or other supports for the bed. The second essential comprises the driving mechanism, consisting of the driving-cone, back gearing, etc., and the third essential consisting of the carriage, tool block, and cutting-tool, with the necessary gearing for moving it, and the connecting

parts for transmitting power for that purpose from the main spindle of the lathe.

This classification of the essential elements of the lathe naturally suggests certain groups of related parts which compose a complete lathe, and correspond with the experience and practice of the author in the designing and construction of the various types of lathes. They are as follows:

1. Bed and appendages, including the legs or cabinets, lead-screw and its boxes, the feed-rod, its boxes and supports, carriage rack, tail-stock, moving rack (when the lathe is large enough to require one), stud-plate and studs, and such necessary bolts and screws as are needed to fasten these parts.

2. Head-stock and appendages, including such feed-gears as are necessary to connect with the feed-rod in case of a geared feed. Also the holding-down bolts and binders (if used), for fastening the head-stock to the bed, and the large and small face-plates. (Where a quick change gear device is used and is not an integral part of the bed or head it forms a separate class.)

3. Tail-stock and appendages, such as holding-down bolts, binders, and, when the lathe is large enough to require it, the mover bracket, gears, shafts and crank; and if the tail-spindle is handled by a hand-wheel in front, the brackets, shafts, spur and bevel gears, etc.

4. Carriage and appendages, including gibs and a solid tool block if one is used, but not a compound rest where these are furnished at the order of the purchaser. If the lathes are habitually built with compound rests they may be classed with the carriage.

5. Apron and appendages, including the apron in its complete assembled form ready to attach to the carriage, together with the screws for making such attachment.

6. Rests, including the compound rest (when not classed with the carriage, the full swing, pulley or wing rest (as it is variously named), center rest, back rest, (when one is furnished), together with bolts, binders, and similar means of attachment.

7. Countershaft and its appendages, including the hangers, boxes, shipper rod, etc., and any similar parts for tight and loose pulleys or friction pulleys as may be necessary to make it complete and ready to put up.

Taper attachments, special tool holders, or tool-rests, and all similar parts are deemed extras and not included in regular lists.

Change-gears are sometimes listed as a part of the bed and appendages. When these are a part of a special quick change device they are made a separate class. This is understood to be when the change gear device is detachable. When made a part of the head-stock or the bed such parts as are attached to the one or the other of these main parts will be listed with it and become a portion of its appendages.

This classification is carried into all lists of materials of whatever kind and into all accounts of labor in the designing, constructing, and handling of these parts, whether in groups or as single pieces, during their progress through the various departments of the shop.

The classification of these lathes as entire and complete machines, and according to their various types of design and construction and the uses to which they are to be put, will be next considered, and in so doing it seems appropriate to commence with the more simple forms, and to proceed with such types as are commonly recognized and in use at the present time, dividing them into four general classes and these into such sub-divisions as their construction and uses seem to demand By this method of classification we shall have:

First Speed Lathes.	Hand Lathes, for floor or bench. Polishing Lathes. Pattern Lathes. Spinning Lathes. Chucking Lathes, with or without a turret.
Second Metal Turning Lathes.	Engine Lathes, without thread-cutting mechanism. Fox Brass Lathes. Forge Lathes. Roughing Lathes.
Third Engine Lathes.	Complete Engine Lathes with thread-cutting mechanism. Precision Lathes. Rapid-Reduction Lathes. Gap Lathes.
Fourth Special Lathes.	Forming Lathes. Pulley Lathes. Shafting Lathes. Multiple Spindle Lathes. Turret Lathes.

In the first class we understand by speed lathes a lathe without back gears and without the carriage and apron of an engine lathe, although as chucking lathes they may be provided with back gears, as they are frequently used for boring quite large holes, and are therefore made much larger and heavier than those of the other sub-divisions of this class.

Hand lathes are supposed to be for the usual operations of hand tool turning, filing and light metal turning by means of a detachable slide-rest. They may have legs of sufficient height to support them from the floor as in Fig. 16, or with very short legs, making

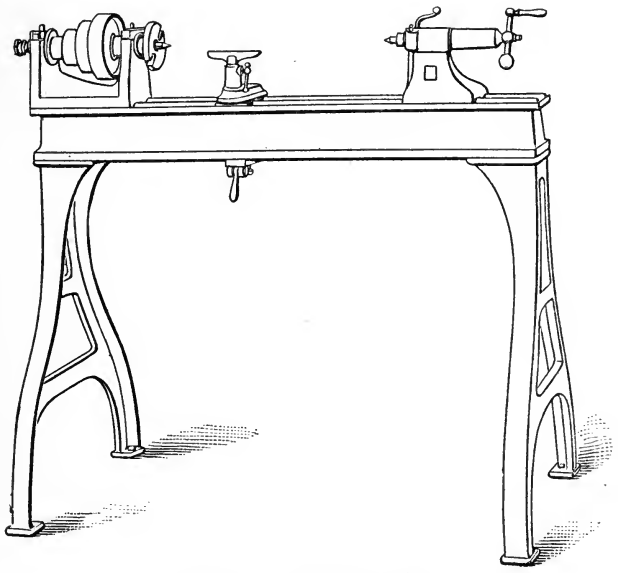


Fig. 16. — A Hand Lathe.

them convenient for setting upon the usual machinists' bench as in Fig. 17. Otherwise their design and construction is the same.

Polishing lathes are, as their name implies, mostly used for polishing cylindrical work, although a hand-rest or a slide-rest is sometimes used upon them.

Pattern lathes, as shown in Fig. 18, are usually so called when used by wood pattern-makers and while usually used with hand tools, as chisels and gouges with the support of a hand-rest, at the present time a majority of them are provided with a slide-rest.

Those of larger swing have the rear end of the main spindle threaded for attaching a face-plate upon which is fixed large face-plate work of too great a diameter to be turned on the ordinary face-plate, as this supplemental face-plate overhangs the end of the bed and consequently the diameter of the work that can be turned is only limited by the height of the main spindle above the floor. In this

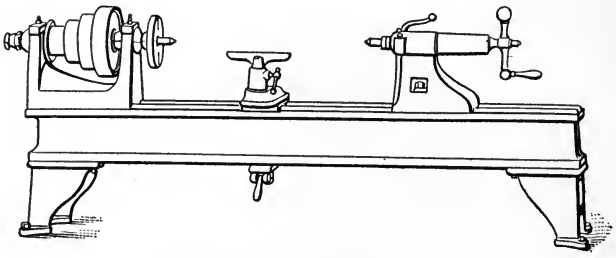


Fig. 17. —A Bench Lathe.

class of work a hand-rest is supported by a tripod stand that may be moved to any desired position on the floor and is heavy enough to stand steadily wherever it may be placed.

Spinning lathes are used for forming a great variety of shapes from discs of quite thin metal, usually brass, with various shaped tools held either by hand or in the tool post of a slide-rest. These tools *form* the metal in a manner similar to the action of a burnisher instead of *cutting* it, usually over a former, by which the same shape is produced in all the pieces. Such work is not usually of large diameter, therefore a spinning lathe is generally of small and medium swing and is of substantially the same construction as the ordinary hand lathe, except when built for large or special work.

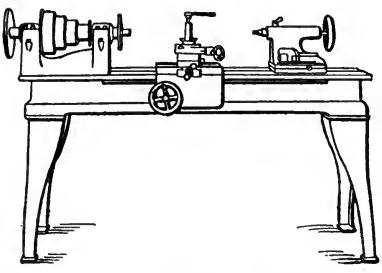


Fig. 18. — A Pattern Lathe.

Chucking lathes, shown in Fig. 19, are used to a great extent for boring and reaming circular castings, as pulleys, gears, hand-wheels, balance-wheels, sleeves, bushings, flanges, and all similar work that require only the formation of the hole, although some

of these machines are provided with a cross-slide and tool-post by means of which the hubs or bosses of the work may be faced. Many of them are now provided with a turret, by means of which several tools may be carried so that not only boring and reaming, but recessing, facing, etc., may also be done without removing the work from the chuck. These lathes usually have a very large driving-cone with a broad belt surface, or they are constructed with back gears similar to those in an engine lathe. It was from this form of lathe that the elaborate lathes built by Jones & Lamson and others of similar design and construction originated.

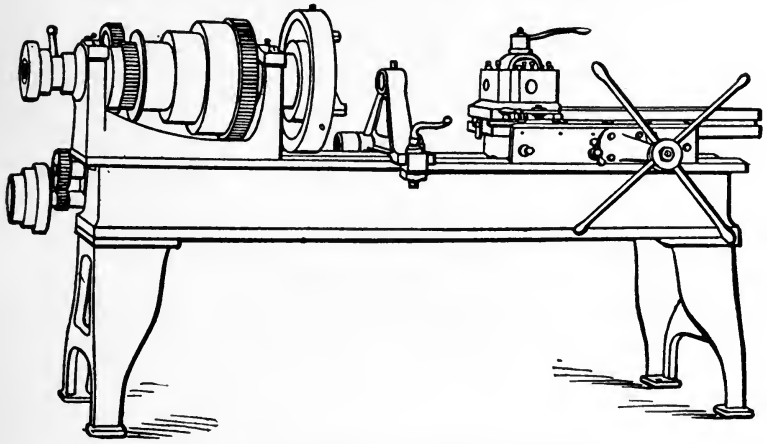


FIG. 19. — A Chucking or Turret Head Lathe.

In the second class we have what used to be called the "plain engine lathe," that is, one not provided with any thread-cutting mechanism. Formerly the smaller sizes of these lathes did not usually have the power cross-feed, although at the present time there are very few of them built by any of the manufacturers, unless by a special order, practically all the modern engine lathes having the thread-cutting mechanism, and frequently it is made an elaborate and expensive feature and covers a wide range of work. When these lathes were built to a considerable extent the feeding mechanism was nearly always driven by a belt, gears being very seldom used for this purpose. No sub-division has been here given for foot-power lathes, as any of those so far described can and have been operated by foot-power when not too large to be thus driven.

The Fox brass lathe, Fig. 20, is built upon similar lines as the engine lathe without a carriage or apron, but in place of it there is a swinging tool post slide whose rear end is journaled upon a lead screw which gives a longitudinal feed when the slide is brought over to the front by means of a handle for that purpose. With this driver, straight turning, facing, and thread cutting is quickly and conveniently done. There is also a hand-rest and sometimes a cutting-slide or cross-slide. The tail spindle has a long run and is sometimes worked with a lever, particularly when chucking work is to be done. Occasionally the tail-stock is replaced by a turret carrying a variety of tools such as are convenient for the

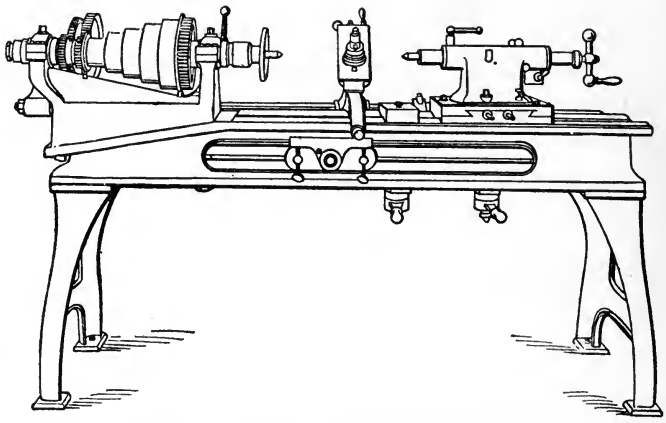


Fig. 20. — A "Fox" Brass Finishing Lathe.

brass finisher. These lathes are usually made without back gears. They are run at very high speeds and in the hands of an expert brass finisher do the work very rapidly, both as to turning and boring or inside finishing, while they cut threads very rapidly by means of "chasers."

Forge lathes are a very heavy design of the plain engine lathe, without thread-cutting mechanism (although some manufacturers add this feature so as to make the lathes available as a complete engine lathe for much work that cannot be classed as forge work). The purpose of these lathes is to rough down large forgings, the users claiming that it is more economical to thus bring the work to the "forging sizes" than to do so by the process of hammer-

ing, and that all the chips thus removed may be worked into other forgings by which this waste is economically recovered. It is therefore their practice to forge the work (cylindrical work, of course) to dimensions much over the forge sizes, and by the use of the heavy forge lathe to finish them to customers "rough turned" to within reasonable limits of "finish sizes."

By the term "roughing lathe" we understand that the design is heavy and massive with a very powerful driving mechanism, lateral and cross feeds and a very rigid tool holding device. Such a lathe is seen in Fig. 21. While it is somewhat analogous to the

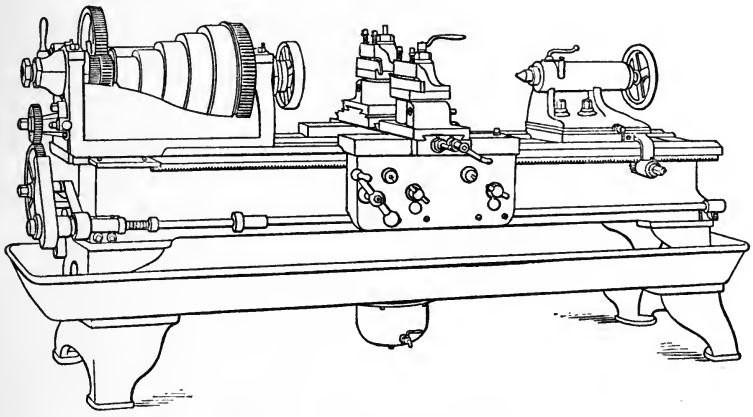


FIG. 21. — A Roughing Lathe.

forge lathe it is usually understood to be of much less capacity. And while the forge lathe, being for handling forgings almost exclusively, holds the work on centers, the roughing lathe should be made with a large hole in the spindle so that work may be "roughed out" from the bar as well as when held on centers, or with one end in a chuck and the other on a center. And here it encroaches upon what may be considered the field of the so-called "rapid reduction lathe"; with this difference, however, that in the former lathe the work is simply roughed out, while in the latter it is supposed to be not only roughed out or *rapidly reduced* to near finished sizes, but in many cases entirely finished, or finished to dimensions suitable for being finished by grinding.

In the third class we commence with the complete engine lathe, with thread-cutting mechanism, back geared or triple geared, with

a compound rest which in the larger sizes is capable of power feed at all angles. Such a lathe should also be supplied, especially in the larger sizes, with a tool-rest to attach to the front wing of the carriage on the left-hand side for turning the full swing of the lathe. The larger lathes, particularly those that are triple geared, should have a tail-stock arranged with two sets of holding-down bolts, by means of which one set may be loosened and the tail-stock set over for turning tapers without removing the work from the lathe, as the other set of bolts still holds the tail-stock to its place on the bed. There should also be a tail-stock moving device consisting of a rack attached to the bed, with which is engaged a pinion fixed to a shaft journaled in a bracket attached to the tail-stock base. By means of a crank on this shaft the tail-stock can be easily moved to any desired point upon the bed.

In lathes of 42-inch swing and larger, this arrangement should be back-geared by the introduction of a second shaft, the gears being in ratio of 2 to 1. In lathes of 60-inch swing and larger this ratio should be 3 to 1. The tail-spindle in the smaller lathes has the usual screw and hand wheel for moving it back and forth. In large lathes this is inconvenient and laborious. The hand wheel should be placed in front of the tail-stock and near the center, being mounted upon a short shaft at right angles to the spindle and journaled in a bracket fixed to the tail-stock. Upon this short shaft is also a miter gear engaging with another fixed to a shaft parallel to the spindle and extending to the rear end of the tail-stock where it passes through another bracket and has fixed upon it a spur pinion which engages a spur gear fixed to the tail-spindle screw, and by which mechanism it is operated. The ratio of this spur gear and pinion is usually 2 to 1 on lathes of 42-inch swing, and proportionately more on larger lathes. By the use of this mechanism the operator may stand opposite the tail center in adjusting his work and easily reach the hand wheel controlling the movement of the spindle, which would otherwise require an assistant to operate.

In the triple-geared head-stocks of this class of lathes it is customary to attach the face-plate to the main spindle by a force-fit and key instead of making it readily removable by a coarse thread, for the reason that it is to be driven by means of a very large internal gear bolted to its rear side and engaged by a pinion fixed

to a shaft driven by the cone through a suitable system of triple back gearing. In this case the cone is not placed upon the main spindle, but upon a separate shaft placed sometimes in front and sometimes in the rear of it. The front position is the more convenient for the operator in making the necessary changes of speed.

It is upon this class of lathes that many improvements have been made in the last few years in the thread-cutting devices, the original idea having been to avoid removing and replacing "change-gears" when threads of different pitches were required to be cut. The first attempt in this line, so far as the patenting of a device shows, was made by Edward Bancroft and William Sellers in 1854, and taken up by various inventors with more or less success but never brought prominently into the market until the patent was granted to Wendel P. Norton in 1892, when somewhat later on the mechanism was adopted by the Hendey Machine Company, since which time it has been manufactured with much success. In the meantime many other devices for the same purpose have been devised and built, so that now every tool room and nearly every machine shop making any pretense to modern equipment possesses lathes having some one of these "rapid change gear attachments" included in their design or arranged to be attached when desired by the customer.

In the development of the engine lathe proper, much attention has been paid to the supports for the bed, and instead of the former pattern of light and, later on, heavy legs, substantial cabinets of liberal dimensions and weight, have been designed and are now used upon nearly all such lathes, the only exceptions seeming to be upon those where the selling price renders economy in the use of cast iron essential; upon lathes too small and light to justify their use; and upon lathes built by the more conservative manufacturers who have not yet come to consider this class of improvements as necessary to the efficiency of their machines.

A precision lathe is designed to be a lathe in which fineness and exactness in all its parts is the prime consideration rather than a great range of work or capacity, or from which a large output may be realized. It is therefore not necessary that it should be very heavy or massive except in so far as its weight may render it capable of greater precision. While the entire design and construction

of the lathe is as exact as possible, the effort is also made to provide against all conditions and causes that shall be detrimental to its one object, that of turning out its work in as perfect a manner as possible.

These being the conditions under which it is designed and built, it is an expensive lathe, as the most skilful labor is used in its construction and the time devoted to this work is always liberal. It is, therefore, essentially a lathe for the tool room and the laboratory rather than the manufacturing department, and with it master screws of very great exactness and all similar work is performed. It is, of course, an engine lathe in its general design,

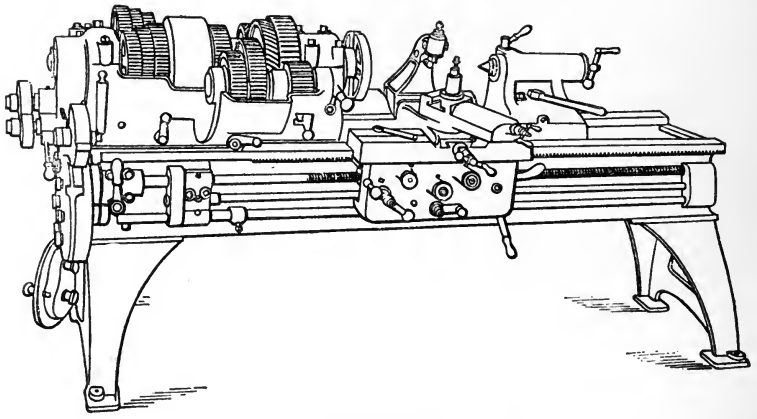


Fig. 22. — A Rapid Reduction Lathe.

although there are more or less changes of form and manner of assembling the parts introduced for the purpose of avoiding the effects of strains, protecting bearings from dirt, insuring accuracy of movement of the several parts, and so on, everything in the design and construction being subordinated to the one condition of the greatest precision and accuracy, not only in the entire machine but in all its individual parts.

The rapid-reduction lathe, shown in Fig. 22, is another form of a complete engine lathe, built heavy and strong, with a powerful and somewhat complicated driving mechanism and very strong feed. The tool holding device should accommodate at least two tools and hold them very rigidly. It should have thread-cutting

facilities so that pieces requiring threads may be entirely finished in this respect. It should be an accurately working machine so that it may not only *rapidly reduce* the stock to near the finishing dimensions, but finish all ordinary work to the given sizes, or to such dimensions as may be called for when the piece is to be finished by grinding. Such a lathe may be arranged with a series of stops both for diameters and lengths and thus do much of the work done in a very much more expensive turret lathe. It will be of much convenience to have a hollow spindle, bored out as large as possible so as to admit of running a bar of round stock through it, holding it in a chuck and forming one end of the pieces, then cutting them off, leaving the remainder of the work on the opposite end

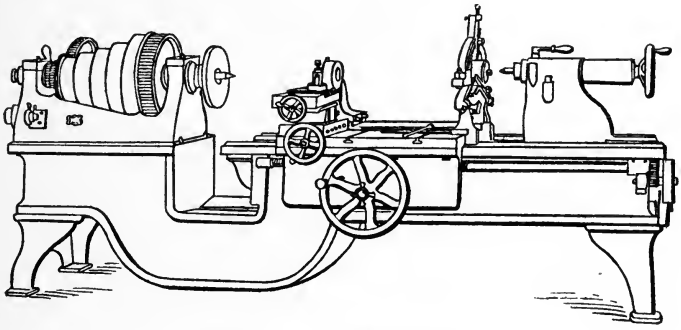


FIG. 23. — A Gap Lathe.

of the piece to be done at a second operation in this lathe or some similar machine. In working up round stock in this manner the lathe should be provided with a cutting-off slide constructed similar to that on a turret lathe.

A gap lathe, shown in Fig. 23, is one in which the top of the bed is cut away for a space immediately in front of the face-plate for the purpose of increasing the swing of the lathe so that much larger work may be turned or bored, either when held upon centers or in a chuck. This type of lathe is more in favor in English machine shops than those of this country, where the gap lathe is seldom seen. When the work of the lathe is not of such a nature as to require the gap, it is usually closed up in one of two ways. The first method is to have a portion of bed exactly like the main part and of such a length that it will exactly fit in the space form-

ing the "gap." The other method is to have that portion of the bed upon which the head-stock is attached, of the full height, while the remainder of the bed is lowered sufficiently to furnish a support for a sliding supplemental bed whose depth is equal to the depth of the gap. This supplemental bed when closed up to the face of the head-stock completes the bed by filling the entire cut-away portion completely to the rear end. When it is desired to form a "gap" this supplemental bed is moved, toward the rear end of the bed proper to any desired distance to leave the required space or gap for the work in hand, and secured by bolts arranged for that purpose. In a large machine shop, with the proper lathes for handling whatever work the shop is called upon to do, the gap lathe is not usually necessary and will seldom be found, but in jobbing shops, particularly those with a modest equipment of tools, the gap lathe may often be found convenient for doing exceptionally large jobs such as pulleys, balance-wheels and the like, as these jobs may come along so seldom that it would not be advisable to incur the expense of a lathe large enough to swing them, and which would be liable to be idle a large portion of the time.

The gap lathe is provided with the usual thread-cutting mechanism and is in all respects a complete engine lathe. It is not usually as rigid as a solid bed lathe and therefore not as efficient in taking heavy cuts.

The fourth class, including the various types of special lathes, would of necessity be a very large one if an attempt were made to enumerate them all, and the list might prove tiresome to the busy reader. Those introduced in the foregoing list are of the well-known and recognized types and seem to be sufficient for the purposes of this work.

Forming lathes are of heavy and massive design and construction, and provided with powerful driving mechanism, adapted to rather slow speeds, and with fine feeds, owing to the large extent of the cutting surface of the tools used in them. These tools require special forms of rest for supporting them which are of strong but simple design, as many of the forming tools are simply flat steel plates with the form to be turned cut in the edge, so that when dull they may be sharpened by grinding the top face and not changing the form. Forming lathes should have hollow

spindles, bored out much larger in proportion than in other types of lathes. The author has designed and built these lathes of 28-inch swing with a spindle $7\frac{1}{2}$ inches in diameter and bored out to $5\frac{1}{8}$ inches, so as to take in a bar of 5-inch steel. As this size weighs about 85 pounds to the foot, or a bar 16 feet long weighs over 1,300 pounds, it will be seen that ample provision was needed for the weight to be borne upon the main spindle bearings in addition to the weight of the lathe parts, and that while the driving power necessary for operating with a wide forming tool on steel of 5 inches diameter was a serious matter, that of providing for the rotating of this unusual load was a considerable addition to it. However, they met the required conditions and succeeded in turning out much work even of this comparatively large diameter.

Naturally the forming lathe requires no provision for thread cutting, but a geared feed should be used and will need to be of ample power to withstand the very severe strain to which it will be put.

Pulley lathes, as they are commonly termed, might more appropriately be called pulley-turning machines, or even pulley-*making* machines, since some of them make the pulley complete, with the exception of splining and drilling and tapping for the set-screws. In some of these machines the boring is going on and the reaming is also done while the turning is taking place. In other forms, one machine does the boring and reaming, which may be done at quite high relative speed, while the turning must be comparatively slower and is done in another machine. Thus one machine for boring and reaming may furnish work enough for several turning machines.

In the pulley-turning lathes there must be a strong driving mechanism since comparatively large diameters are turned, although even the roughing cut is light when compared with that frequently taken by other lathes. Two and sometimes more tools are used, being located both at the front and back of the bed, (those at the back being bottom side up). In some machines the tools commence the operation in the center of the face of the pulley, and each tool or pair of tools (one roughing and one finishing), are fed away from the center, and with the slide upon which the tool block travels set in a slightly inclined position with reference

to the axis of the lathe so as to produce the properly "crowned face" of the pulley. With four tools thus arranged, the pulley is completely turned during the time necessary for a tool to travel across one half of the face of the pulley plus the distance apart of the roughing and the finishing tool, say from an inch to an inch and a half.

When the pulley-turning lathe is arranged for turning cone pulleys it is customary to have as many tools as there are steps to the cone pulley, each held in a separate tool post fixed in a single tool block having a lateral power feed and a transverse adjustment for setting to the proper diameter. The tool posts set in T-slots and the tools are set with relation to each other so as to turn the proper relative diameters of the several steps. The tool block and the slide upon which it runs is adjustable to the right inclination or "taper" to properly crown all the steps of the cone at once, and when the tools have passed over one half the face of the steps, this block and slide may be shifted and properly adjusted to turn the other half of each step. In this form of pulley turning it is usual to make two cuts, a roughing and a finishing cut, and when turning up to the face of the different steps to draw back the entire number of tools by means of the transverse slide which may be fed back by hand for that purpose.

Pulley-turning and boring lathes or machines are built very broad as compared with an engine lathe and with very short beds, as the width of a pulley face, or the combined faces of the several steps of a cone pulley, is the extent of their lateral feed in any case.

The boring and reaming mechanism should have a power feed so as not to require the constant attendance of the operator, who may easily run one boring and reaming machine and two surface turning machines.

Shafting lathes or shaft-turning lathes may be arranged from any good engine lathe provided the bed is long enough for the purpose, by adding to it a three-tool shafting rest and a shaft straightener. Still a lathe that is especially designed as a shaft-turning lathe will be better adapted for the purpose and will turn out more good shafting with the same expenditure of capital and labor than the engine lathe arranged with attachments for the purpose. In the properly designed shaft-turning lathe there is a

heavy shaft running the length of the lathe bed and arranged to communicate power to a face gear and driver journaled on the front end of the tail-stock, by means of which the shaft to be turned may be driven from this end as well as from the head-stock end. This is very useful in turning long shafts in which the torsional strain would be great, as the power may be applied at the tail-stock to turn one half of the shaft and then applied direct from the head-stock, or it may be applied at both ends continuously and simultaneously.

There should be a force pump to keep the cutting-tools constantly supplied with a stream of whatever lubricant is being used. This pump may be driven from the shaft above mentioned, which is located at the center of the bed and below the bridge of the carriage. The three-tool rest carries its own center rest, but it is customary to support the shaft being turned by easily removable rests used between the carriage and the head-stock or tail-stock, as the operator finds necessary. These are generally composed of two wooden blocks resting on the V's of the lathe and somewhat lower than the lathe centers. The upper block has a V-shaped groove for the shaft to rest in and is raised up and held in place by a wooden wedge inserted just far enough to give proper support to the shaft so as not to permit it to sag during the process of turning. There are three turning tools usually employed. The first is a roughing tool; the second cuts the shaft very closely to size, while the third takes an extremely light cut, completing the work, so that by running once over the shaft from end to end it is completely finished. Two tools are placed at the left of the center rest fixed to the tool block, and one, the final finishing tool, at the right. As these three tools and the center rest occupy considerable length upon the shaft the lathe is provided with extra long centers so as to reach the work. The center rest is provided with split collars bored to the size that the second tool leaves the shaft.

The turret lathe, shown in Fig. 24, now so well and favorably known, is a comparatively recent invention and doubtless originated in the use of a multiple tail-stock which was formerly used on small work where more than one tool was desirable. Our English friends recognize its value and usefulness, and one author speaks of it as "the common capstan tool-rest." In this country much

has been done to develop and bring into popular form the turret lathe by such builders as Jones & Lamson, Warner & Swasey, Potter & Johnson, Bullard and others.

While the turret lathe in its perfected form is now a complete machine, the turret idea was first applied to engine lathes, and turret attachments are so universally popular that most of the lathe manufacturers now make them of dimensions suitable for their lathes, and attach them either to the lathe carriage or to a special bed which may be fastened to the lathe bed upon the removal

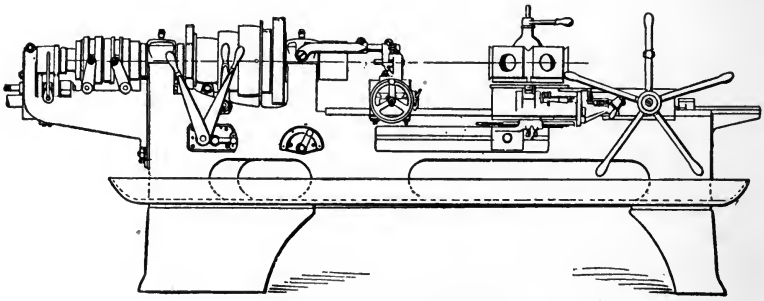


FIG. 24. — A Turret Lathe.

of the tail-stock. A great variety of work may be done in the turret lathe, its principal rival being the automatic screw machine, whose economy lies principally in the fact that one operator may take care of a number of machines, each of these machines depending principally for their success upon the turret with its multiplicity of tools. And this idea of a turret carrying from four to eight tools is applied in a great variety of ways and to a large variety of machines on account of the ease with which any desired tool may be brought into a working position.

The head-stock of a turret lathe is made in several ways, from that of a plain head without back gears to one with a large variety of speeds, controlled by handles operating clutches, or friction driving devices, or both, and which may be operated while the machine is in motion. In some cases the head-stock is cast in one piece with the bed, in others fitted to it in a similar manner to that of an ordinary lathe. In still others the head has a transverse movement on the bed upon which it slides and its movement is easily controlled by the operator.

The turret is designed and constructed in a variety of forms, but principally either circular or hexagonal. It is mounted usually in a horizontal position, that is with its axis vertical, but still in some of the best machines, notably the Gisholt, it is pivoted in an inclined position, the object being to bring the long tools, made necessary by a large machine, up out of the way of the operator as they swing over the front of the machine.

In the smaller hand machines and in many of the turrets furnished upon ordinary engine lathes the turrets are rotated by hand as each change is required, but in the larger and more complete machines the sliding movement of the turret effects its rotation at the proper time near its extreme rear position.

There is no carriage, properly so called, upon a regular turret lathe. A cutting-off slide carrying two tool-posts, one in front and one in the rear, serve to carry a cutting-off tool and a facing tool, or one for doing forming within certain limits. The spindle being hollow, and a large part of the work of the turret lathe adapted for steel work being made direct from the bar, these tools are very useful.

Some turret lathes are particularly adapted for a large variety of chucking and forming work, which they perform very accurately and economically, an elaborate system of stops for the turret slide rendering them very efficient for this work.

The tools that may be used in a turret are almost without number, and the expert operator readily attacks the most complicated pieces and brings them out with excellent finish and with surprising accuracy. Internal and external threads are readily cut very true to size and with rapidity.

The screw machine is very closely allied to the turret lathe, so called, and the smaller sizes are fitted with what is called a "wire feed," which will automatically feed in the bar against the turret stop as soon as it is released by opening the chuck. This is in the hand screw machine. In the automatic screw machine all these movements are made automatically when once the machine is set up, the tools properly adjusted, the bar of stock once introduced and the machine started, and, barring accidents, the machine continues to run, dropping its work into a pan as it is completed and cut off, until the bar of stock is almost entirely used up.

Multiple spindle lathes are usually those having two spindles. These may be side by side for the purpose of performing two similar operations simultaneously; or one spindle may be considerably higher than the other, above the bed, thus giving two different capacities as to the diameter of work that can be accommodated on the same lathe; the larger swing being frequently used for boring or similar work. Notably of this type of lathe is that put in the market by J. J. McCabe.

While the general and well-marked types of lathes have been specified in this classification it must not be understood that the list is complete, as there are many special lathes, each of excellent mechanism and well adapted to the special work for which it is designed, that do not appear here, and that it is manifestly impossible to classify and describe in detail. Frequently they may be assigned to some one of the classes or sub-divisions here set forth, as all lathes must partake in some respect of the essential parts of those described.

Further on in this work many practical examples of the lathes described in this chapter will be found, their builders' names being given and their particular features pointed out and commented upon, and to them the reader is referred for the better examples of each of the classes enumerated in this chapter.

CHAPTER IV

LATHE DESIGN: THE BED AND ITS SUPPORTS

The designer of lathes. The manufacturer's view of a lathe. The proper medium. Cause of failure. The visionary designer. Conscientious efforts to improve in design. Design of the lathe bed. Elementary design. Professor Sweet's observations. The parabolic form of lathe beds. The author's design. Form of the tracks. Bed of the old chain lathe. The English method of stating lathe capacity. Method of increasing the swing of the lathe. The Lodge & Shipley lathe bed. Uniform thickness of metal in beds. Ideal form of bed. Cross-ties, or bars. Four V's. Flat surfaces. Lathe bed supports. Height of lathe centers. Wooden legs for lathe beds. An early form of braced, cast iron legs. Cabinets or cupboard bases. Old style cast iron legs still in use. Form of cabinets. Principles of the design of cabinets. Cabinets for small lathes. The Lodge & Shipley cabinet. The Hendey-Norton cabinet.

To the experienced and conscientious designer of machine tools the condition is frequently forced upon him that it is often easier, and usually far more agreeable, to design machines as he really believes they should be, than to design such machines as will meet the popular requirements of the market. He may be sure that a certain plan would make really a better and more efficient machine, yet he must, from the outset, consider the kind of a machine the customers want and will buy and pay for, since they are, as has been often said, "the court of final resort" in the matter, and machine-tool builders manufacture machines to *sell*, and not for the purpose of exploiting individual opinions, however good they may be, or the fads and fancies of draftsmen who are sometimes imbued with visionary and impractical ideas.

The manufacturer himself may be perfectly sure that the machines he is turning out are not the best adapted for the purposes for which they are used, or the best he could build for the money.

He may so far have the courage of his convictions as to build for his own use machines quite different from those he manufactures for his customers. Yet for *sale* he must build what his customers want with small regard for his own personal opinions.

By this it is not meant that the builder does not use his judgment in a mechanical way, or that he does not endeavor to build the best machines possible, inasmuch as he does give this very question much time, attention, and study. Yet he must, from the very nature of the case, always keep in mind the question, "What will the customers think of this new machine?" "Will this device be a success, or will it prove a failure?" Some machines that have been put on the market with feelings of much trepidation have proven great money-makers, while other machines possessing much mechanical excellence have fallen flat and a large majority of the customers refused to endorse them. The author has seen many such cases, and this has probably been the experience of every man who has designed and built machine tools.

The proper medium in the matter seems to be to keep as closely in touch as possible with the purchasers of machinery; to ascertain their needs and preferences as closely as may be; to anticipate their wants when possible, but at the same time with conservatism; and to avoid putting entirely new devices on the market until they have been thoroughly tested in the home shop and by a few friendly shops outside of it. And by entirely new devices is meant substantially new and complete machines, as the builder will frequently have parts of, or attachments to, the regular line of machines that are made to the order of a particular customer and that he feels perfectly sure of being well suited to the work that it is expected to perform; yet in these cases considerable caution is necessary.

The one fruitful source of difficulty, disappointment, and failure to be most avoided in the production of new devices is the mania often manifested by designers to produce something absolutely new, decidedly novel, the like of which no one has ever seen or dreamed of, and that will startle the mechanical world, revolutionize the business, and prove its author a veritable Napoleon of mechanical science.

When confronted with such a man or such a condition, the

wiser course will be to abandon such ambitious attempts to eclipse all previous efforts, get down out of the clouds, design something of practical utility, even if it is not strikingly new; something that past experience gives some guarantee of success; something that will surely bring the proper financial return and be a credit to the shop. It is always well to remember, when tempted to go off on a tangent after something new and marvelous, that "a good adaptation is better than a poor original," and that when Solomon said that "there is no new thing under the sun," he did not come far from the truth, since many of the things *we* think are new may be found in almost the identical form, that have been invented, used, and discarded years ago, as the records of many mechanical libraries as well as the United States Patent Office will furnish abundant evidence.

By the foregoing remarks it is not intended to discourage originality, original thought and research, or the proper ambition to improvement, for we often produce more of real value by the effort to evolve mechanical improvements than by the design of entirely new machines, and the studious and observing designer will always be on the alert to devise improvements upon existing forms and processes.

These observations and suggestions apply with as much force in the efforts to improve the lathe as any other machine in common use. Being the oldest machine in the machine shop does not in any respect limit the field for improvements in it. Neither does it preclude the design of entirely new machines that may have, perhaps, very little of the characteristics of a lathe, although we must necessarily be confined to the essentials heretofore discussed, namely, a bed, upon which rest the head-stock, tail-stock, and carriage, or their equivalents, if we would claim that our machine is a lathe.

With these preliminary statements relative to the conditions and requirements of good and successful designing, we may take up the designing of lathes somewhat in detail and inquire into the design of the individual parts and groups of parts, giving some of the ideas of men prominent in this field, and adding such comments and suggestions as seem proper and pertinent to the case as the matter is proceeded with.

In carrying out this plan it will be natural to commence with the bed, considering its use and purpose, and the proper form to fulfil the requirements of this particular part.

The lathe bed, considered in an elementary way, and in the case of a lathe of moderate length, may be taken as a beam, supported at each end and in its turn supporting at one end the head-stock, at the other end the tail-stock, and in the center the carriage, as represented in Fig. 25.

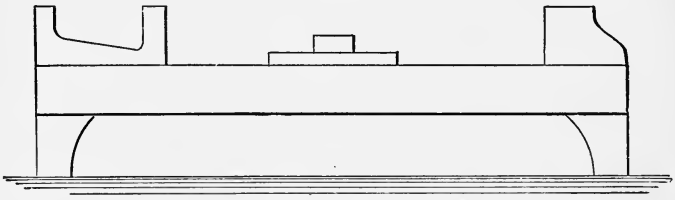


FIG. 25. — Elementary Form of Lathe Bed.

This being the problem, and as the head-stock and the tail-stock stand directly over the legs or supports, we might consider the problem as that of a beam loaded at the center, which would naturally suggest that the under side of the bed instead of being straight should be a parabolic curve. This would result in the form shown in Fig. 26, which would, if the carriage was stationary,

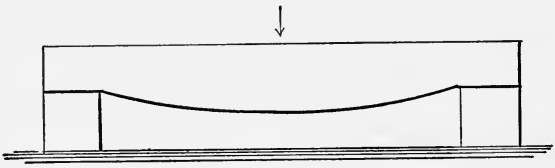


FIG. 26. — Parabolic Form of Lathe Bed.

conform to the conditions of the problem. But, while the carriage is not stationary, it is located at what would normally be the weakest point along the length of the bed, namely, a point farthest from either support. So far the parabolic curve, then, is correct.

But while we have been placing our supports at the extreme end of the bed we have no condition of the case which makes it incumbent upon us to do so. In other words, we may add a portion to each end of the bed, outside of, or beyond the line of these supports, in the form shown in Fig. 27, showing a modified form

of the lathe bed, the extensions at each end being in the form of a beam supported at one end. Theoretically, then, this would seem to be the proper form of a lathe bed in order that it might conform to the necessary requirements as to form and its ability to sustain the usual weights and strains to which it will be subjected, and at the same time not be of excessive weight, which would entail unnecessary expense.

This is substantially the view taken by Prof. John E. Sweet in reference to machine beds. He says:

"No reasoning can make it out that the place for the support of an ordinary sized lathe bed at the tail-stock end of the lathe is at the end. If placed a considerable distance from the end, and the tail-stock is at the end, it is better supported than when in the middle of the present style of lathes and also better supported at

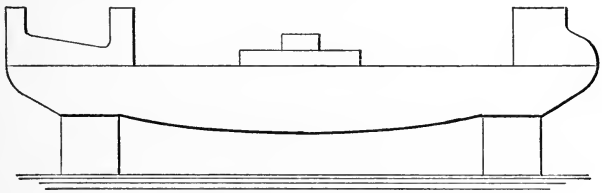


Fig. 27. — Modified Parabolic Form of Lathe Bed.

all other points. At the head-stock end it is quite a different matter as the head-stock is always fixed and is usually heavier loaded, exclusive of its own greater weight. Where the head-stock end support is a closet, there is no way to make it look right except to have the closet the same width as the head-stock is long.

"In the case of a planing machine bed up to 12 or 15 feet in length there is no reason for having three pairs of supports. Unless the foundation is absolutely unyielding — a thing that is more rare than the other kind — the three or more pairs of supports are especially bad, and to attempt to hold the foundation true with a frail planer bed is foolish. The distance between the supports in Fig. 28 is no greater than in 29, and as in no case would the center of the load in planing overhang the supports more than a slight distance the style shown in Fig. 28 is quite as well supported as the other; and when the iron in the legs and the work to fit them are taken into account, if they were all put into the casting the bed

could be brought down to the floor as in Fig. 30, greatly improving the structure.

"Another improvement is to use the iron usually put in the cross-

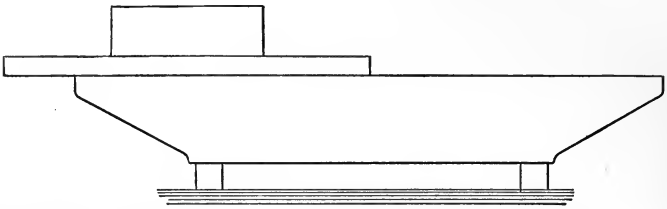


FIG. 28. — Prof. Sweet's Form of Bed, supported at Two Points only.

girts — which do not stiffen the bed in any way to any great extent — and use it in bottom and top webs, making the thing a four-

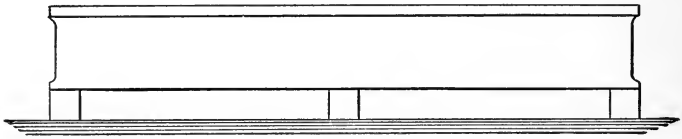


FIG. 29. — A Common Form of Lathe Bed, Supported at Three Points.

sided box, which is from four to a dozen times stiffer in all directions, and then rest the whole thing on three points, one under the

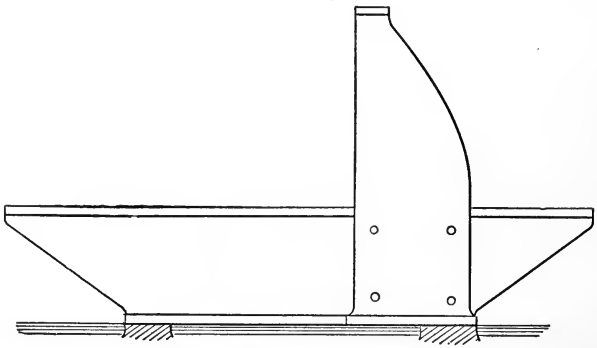


FIG. 30. — Prof. Sweet's Design Applied to a Planer Bed.

back of each housing and one under the middle toward the other end. The whole thing, including patterns and setting, will cost no (or very little) more and be four times better than present practice.

"If the bed is supported at the same points when it is planed and fitted up, no attention or skill is required in the erection — just set it anywhere and on anything solid, and that is all that need be or can be done."

There is "meat for reflection" in what Professor Sweet says (as there usually is), and the principle upon which he makes his deductions is undoubtedly correct.

To render the comparison more apparent and in a practical manner the two views shown in Figs. 31 and 32 are given. In

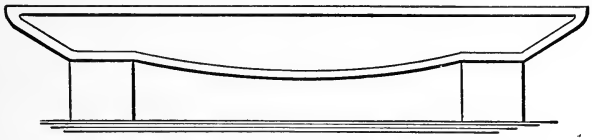


FIG. 31. — The Parabolic Design of a Lathe Bed.

Fig. 31 the parabolic design is shown in proper proportion for supporting the head-stock, tail-stock, and carriage, and the proportions laid out are ample for all purposes, as is also the supports and their distance from each other. In Fig. 32 is shown a rectangular design of bed of like length and of sufficient depth to give the requisite strength, provided there is a central support added to prevent a sinking in the center of the bed, as the distance between supports would otherwise be too great. While nothing has been added to the strength or the stiffness of the bed, we have been

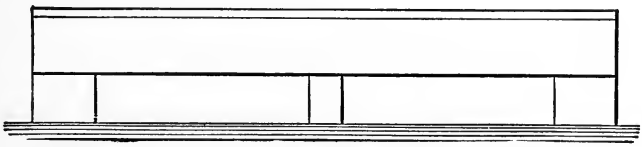


FIG. 32. — The Rectangular Form of Equal Strength.

obliged to add the central support and in addition to this the weight of the parabolic form of bed is 1,390 pounds, while the rectangular form is 1,550, a very material addition without compensating advantages; and at the same time we have the disadvantage referred to by Professor Sweet, that the nearer together we can get the supports and still retain the condition of rigidity the less we shall have to depend upon the correctness of the foundations,

and this of itself is a matter of very important consideration, since in some of the popular forms of machines their truth and correctness depends to a very considerable extent upon the accuracy and continued stability of the foundations upon which they rest.

It was from such considerations and conditions as has just been illustrated and described that the author designed and built the 21-inch swing engine lathe shown in Fig. 33. This lathe met with exceptional success in the market both in a mechanical and financial way and a large number of them were built and sold, although they were brought out during a season of great depression both in mechanical and financial circles, when hardly a machine

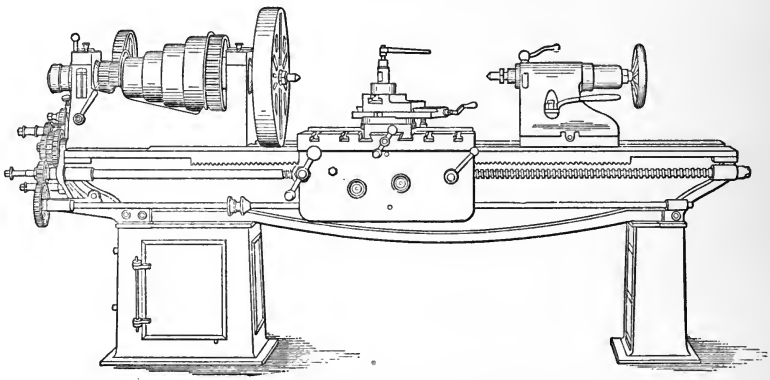


FIG. 33. — A 21-inch Lathe with the Parabolic Form of Bed. Designed by the Author.

shop in the country was running full time, and many of them but eight hours a day for three days only in a week. After a couple of years these beds were changed to the rectangular form in order to satisfy the demands of customers, the depth being nearly as great as the one here shown is in its deepest part, and the weight much increased. The ends were made square and the rear box leg made a regular cabinet similar to the front cabinet. The lathe is still built with very little change in its general design except as above specified, although it was originally designed over a dozen years ago.

It will be noticed in the design shown in Fig. 33 that the front end of the front cabinet is in a vertical line with the front end of the head-stock, as suggested by Professor Sweet, and about twelve

years before his article was published, although it is probable that he had held the same opinions therein expressed for a much longer period than this would indicate.

There is much diversity of opinion as to the proper method of designing the "shears," "ways," "tracks," "V's" or by whatever term we may designate the top portion of a lathe bed.

It has been shown in the "old chain lathe," Fig. 13, when beds were made of wood, that the V's were made of strips of wrought iron set on edge and fastened in rabbits cut in the wooden bed, their upper edges chipped and filed in the form of an inverted V. There were only two of these, the head-stock, tail-stock and carriage, all resting upon the same V's. Consequently, the carriage was not able to run past the head-stock or the tail-stock, as is the case with the modern lathe-bed having four V's.

The usual form of construction is shown in cross section in Fig. 34, which is drawn to the usual proportion of the component parts of a bed. As a matter of strength, stability, and rigidity, the center, at the top, of the inside V's A, A, and the lathe center or center of the head spindle B, should form an equilateral triangle. An arc C, of a radius struck from the center B, and just clearing the V at A, will be the radius of the swing of the lathe

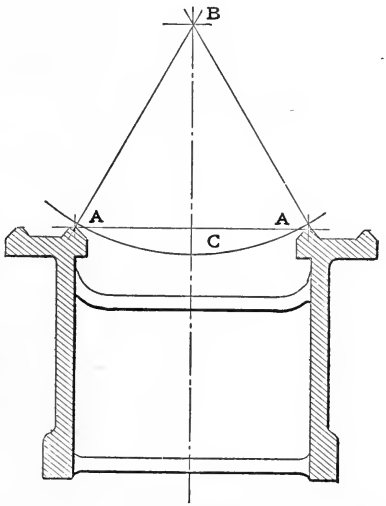


FIG. 34. — The Usual Form of Cross Section of Bed with Four V's.

This matter of determining "the swing" of a lathe differs materially as between the practice of this country and England. An English author, Mr. Joseph Horner, states it thus: "The 'centers' signifies the distance from the top face of the bed to the centers of the spindles. English and continental lathes are designated thus, but American by twice the centers, or the 'swing,' in other words — the maximum diameter which a lathe will carry over the bed." And with all due respect to the opinions and prac-

tice of our cousins "on the other side," it would seem the proper designation, and the one in which a prospective purchaser would be most interested, to tell him how large a piece of work could be done in the lathe, rather than to tell him the half of this diameter, or the radius, and let him have the trouble of the mental calculation of multiplying this dimension by two every time it is mentioned. It may seem all right when one is accustomed to it, but, like the English monetary system of pounds, shillings, and pence, it seems unnecessarily cumbersome when compared with the directness of the American expression.

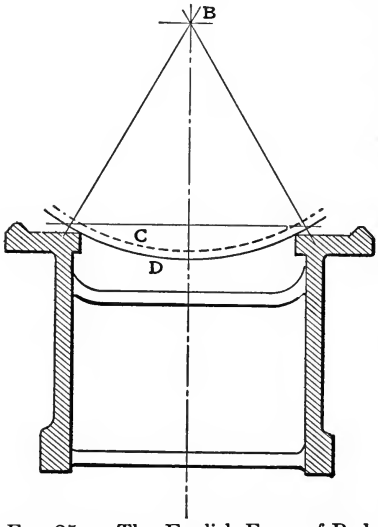


FIG. 35. — The English Form of Bed with only Two V's.

In order to increase the swing of the lathe without raising the head spindle in relation to the bed, some builders prefer to omit the inside V's, as shown in Fig. 35, by which means the arc C, as given in Fig. 34, and here shown as a dotted line, is increased to the arc D, and the swing of the lathe increased by twice this difference. In this case the headstock and the tail-stock are both fitted to the flat top of the bed and also have a projecting rib or its equivalent built down and fitted to the inside of the inwardly projecting flange of the top of the bed. This method of construction is that in use in English and continental lathes and in recent years has been adopted by some lathe builders in this country.

Still another method for increasing the swing is shown in Fig. 36. This is by lowering the inside V's, upon which the headstock and tail-stock rest, and leaving the outer V's supporting the carriage in their original position. In this engraving the arcs, representing the radius of the swing in the two former examples, are shown in dotted lines, and the increased arc E by a full line. There are other advantages in the form of construction shown in Figs. 35 and 36, which will be noticed later on.

In Fig. 37 is shown the form of bed adapted by Lodge & Shipley, which will be seen to be a modification of the preceding examples in that, in this case, the English form of a flat surface is used in place of the front V, while at the rear the inverted V-shape is retained. There are several advantages in this form. The rear V is preferred by some as a better method of locating the head-stock and tail-stock in perfect alignment, inasmuch as that while the head-stock, once located and securely bolted down, remains in its fixed position whether resting on V's or upon a flat surface and

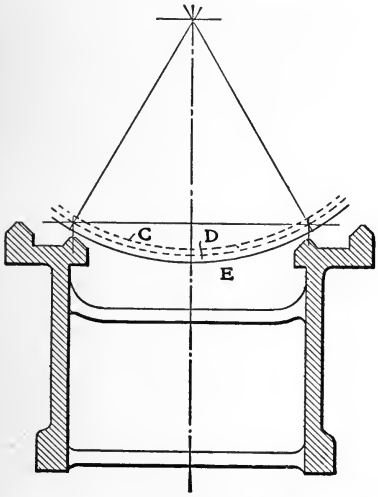


FIG. 36. — Bed with Depressed Inside V's, giving Increased Swing.

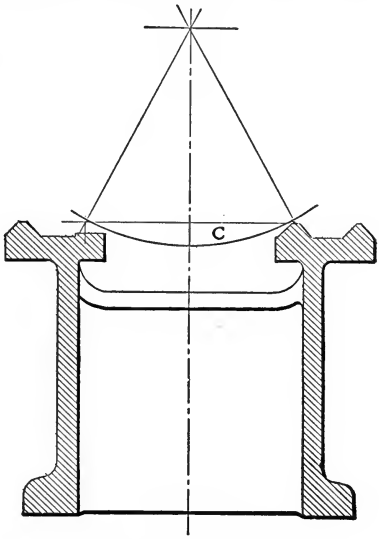


FIG. 37. — The Lodge & Shipley Form of Bed.

between vertical faces as in the English lathe. With the movable tail-stock this is different. There is a constant tendency to wear in all directions of contact, and if fitted between vertical surfaces this tendency will in time throw it out of line. When resting upon the inclined surfaces of the inverted V, the wear is likely to be equal on the two sides and the lateral alignment is maintained, while the vertical wear will be considerably less than that of the head spindle in the boxes, which should be vertically adjustable to compensate for this wear and so a proper and perfect alignment of the two be maintained.

The bed shown in Fig. 37 is considerably deeper than the former

examples, but corresponds very nearly to the proportions that have been found necessary to the proper strength and rigidity of the modern lathe when used under the severe strains and hard usage incident to modern shop methods and to the use of high-speed tool steels, with the necessity for the rapid reduction of the diameter of the stock which would in former times have been considered very wasteful of materials, but which in these days of cheap machine steel are much more economical than the usual processes of forging the parts to nearly the diameters necessary, as was formerly the usage when the price of steel was very much above what it is now and the cost of labor considerably less.

It will have been noticed in the engravings of the cross sections or beds thus far given, that the "side plates" or outer walls have been uniform on the two sides and across the ends. Also, that the bed is very much strengthened by the track or flat upper member. To obtain a casting of nearly uniform shrinkage throughout, and to diminish as much as may be the unequal strains, as well as to add to the strength and stiffness of the bed, the lower edge has been reenforced by an additional thickness for a short distance from the lower edge. This has been made of different forms by different designers, but is substantially as shown in these engravings.

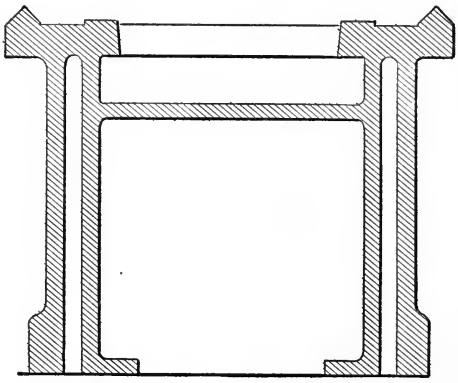


FIG. 38. — Ideal Form of Bed to Resist Torsional Strains.

In Fig. 38 is shown an ideal form of bed combining great strength and stiffness with a minimum amount of material when its rigidity is considered. Much is said in machine tool design of the "box form," and while in some instances its merits may have been overrated it certainly is a form possessing most excellent qualities of strength, stiffness, and power to withstand torsional strains as well as to rigidly support heavy loads. It is for these reasons that this bed is designed as it is, and for these reasons it seems fair to

call it an ideal form. The entire length of the sides or "side plates," are double, or of the "box form," tied together at frequent intervals so that the outer and inner wall properly support each other. To "balance the casting," there is not only an additional thickness of metal at the bottom of the outer wall, on the outside, but an inwardly projecting flange along the inside of the inside wall at the bottom. As far as possible the casting and all its component parts are of as nearly as may be the same thickness, so as to reduce to a minimum the internal strains of the casting as it cools after being "poured."

A further reference to the form and disposition of the cross-braces or cross-ties is made a little further on in describing these members of the casting.

Thus far the cross section of the bed, and its component parts of the side plates, the track or top portion and the V's, have been

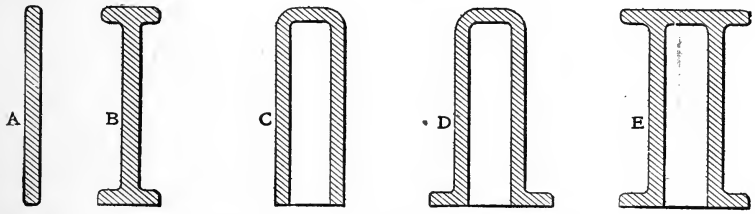


FIG. 39. — Forms of Cross-Ties or Braces.

shown, in addition to the front elevations and the various forms of beds for supporting the weight of the head-stock, the tail-stock, and the carriage. The next feature to be considered will be the "cross-bars," or "cross-ties" as they are sometimes called.

The cross sections of these various forms are shown in Fig. 39 at A, B, C, D, and E, which give the principal forms in common use. At A is the simple form or single bar, set on edge and used in the earlier forms of cast iron lathe beds for many years. The desire to get some form more rigid laterally led to the addition of a horizontal rib, first on the top edge only and then on the bottom also, making the I-beam section shown at B. This was for many years considered quite sufficient for the purpose until the desire for more strength and stiffness led to the adoption of the "box form" shown at C. Later on this form was still further strengthened by the addition of outwardly projecting ribs or flanges at the bottom

edges forming the section that is shown at D. To this form has since been added the top ribs as shown at E, and the question has, for the time at least, been solved, of making as strong and rigid a cross-bar as is possible.

It will be noticed that wherever these forms are with double walls the internal space is closed at the top. This occurs, first, as the bed is cast bottom side up, and it is more convenient to pour the molten iron into this form and have a solid casting; it gives a better appearance to the top of the cross-bar in the finished lathe; and a cross-bar open at the top would furnish a receptacle for dirt, chips, and small articles that would occasionally drop into it.

These cross-bars were located at right angles to the length of the bed as shown in plan in Fig. 40, their distances apart in

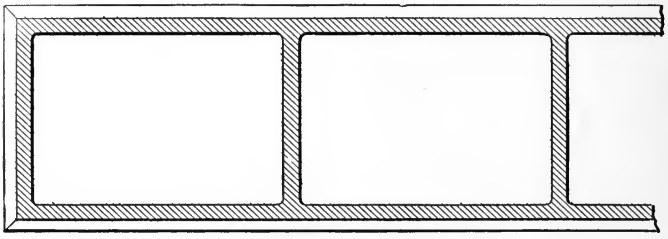


FIG. 40. — The Usual Manner of Placing the Cross-Ties.

the earlier forms of beds being two or three times the width of the center of the bed. This distance was gradually reduced as the beds were made heavier and stronger, until ten or fifteen years ago it was frequently the case that the cross-braces were spaced considerably less distance apart than the width of the bed, particularly in the wider beds used for heavy lathes, say from 36-inch swing and larger. This method of locating them prevailed in the use of the forms shown in cross section at A, B, and C, Fig. 39.

As still stronger and more rigid beds were called for, the braces were placed at an angle, generally crossing each other, and of the form and proportion shown in plan in Fig. 41. In this case it was usual to use the forms shown in cross section at B, C and D, Fig. 39. The angle at which these were set was varied by different builders, that here shown being 45 degrees, and the most usual angle used.

In Fig. 42 is shown a plan of the ideal bed, a cross section of which is shown in Fig. 38. These cross-braces are made of the

sectional form shown in Fig. 39, at E, and are placed at an angle of 30 degrees with the side of the bed, and in the illustration the spaces between the walls of the braces as well as the bed are shown, and also the proper spacing from the head end of the bed. It will be readily seen that such a form of casting insures great stiffness and rigidity and guarantees the casting against torsional

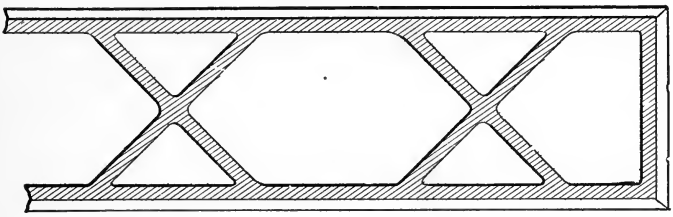


Fig. 41. — Angular Bracing with the Cross-Ties.

strains, as well as against unequal strains as the casting is cooling. As a matter of design in providing a rigid bed this form seems to realize all the desirable qualities that leave nothing more to be desired. Yet it is possible that in the continual development of the lathe, better methods and stronger beds will be brought out, for what we consider to be of ample strength to-day may be relegated to the scrap-heap a dozen years from now.

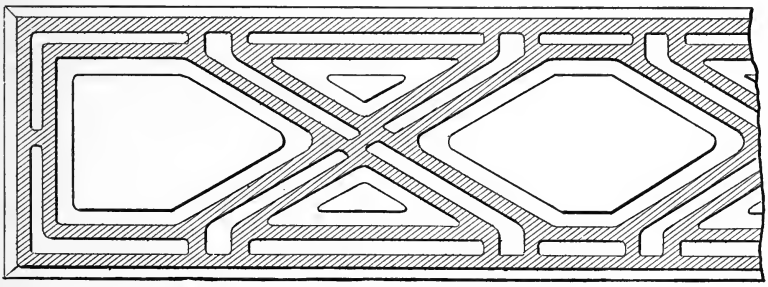


Fig. 42. — Ideal Manner of Arranging Angular Bracing with Cross-Ties.

The form of the "track" or upper portion of the lathe bed has much to do with the form and strength of the carriage which it supports. In the early form of wooden beds, with two V's formed from wrought iron bars set upon edge and chipped and filed to the inverted V form, with the head-stock, tail-stock, and carriage all resting upon them, the carriage had, of necessity, to be made

with scant bearing on the V's, that is, very narrow, measured along the length of the bed, as it could not pass the head-stock and the tail-stock as the "wings" of the carriage do in the later forms of bed with four V's, or their equivalent. Consequently, the head center of the lathe had considerably more "overhang" than it has at present, in order to permit the tool to be worked up near the lathe center; and the same was true of working up closely to the tail-stock center.

With the advent of cast iron beds four V's were usually provided for. Whether the idea of four V's came in with the cast iron bed is not certain, as it is entirely possible that some ingenious machinist fitted the wrought iron strips, not only to the *inside* but to the *outside* of the two wooden beams composing the bed, and so

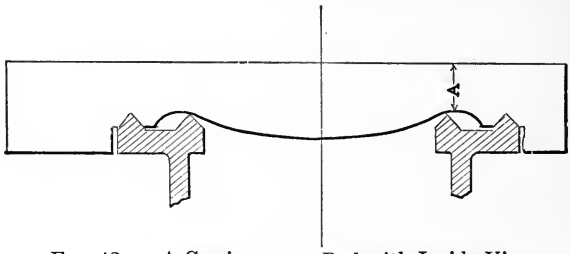


FIG. 43. — A Carriage on a Bed with Inside V's.

accomplished the same results as to providing a "wing carriage," capable of passing the head-stock and the tail-stock as we have them to-day.

The lathe bed with four V's and the carriage suitable for it is shown in Fig. 43, by which it will be seen that the portion of the carriage coming over the inside V's at A must be cut away so as to clear them entirely, as the carriage must rest wholly upon the outer V's. The necessity for this cutting away to clear the inside V's is a source of weakness to the carriage, and the only way to compensate for it is to make this part of the carriage broader, which does not add much to its strength, or to make it deeper, which lessens the capacity of the lathe by decreasing its possible "swing over the carriage."

In Fig. 44 is shown the effect when the inside V's are omitted, and the carriage at A may be made of much greater strength without raising its top line so as to decrease the swing over the carriage.

It is clear that so far as the convenience of design and the strength of the carriage is concerned this form of bed is preferable to the one having four V's. There is one disadvantage, however, which occurs in fitting the head-stock and the tail-stock to this vertical inner surface of the "track" at B, B. The head-stock, being fixed to the bed, may be tightly fitted and remain so, but the tail-stock,

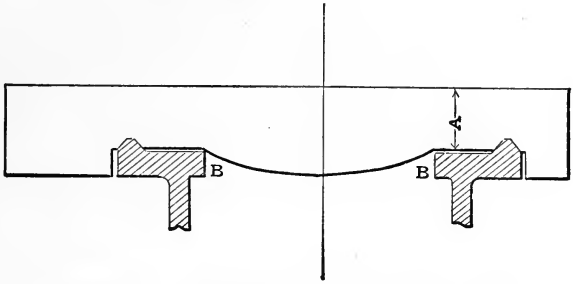


FIG. 44. — A Carriage on a Bed when Inside V's are Omitted.

from its being a movable part and frequently run back and forth, will in time wear sufficiently to throw its center out of line with the center of the head spindle. This disadvantage may be obviated by making these vertical surfaces B, B, slightly inclined.

This inclination to the inner surfaces of the track of the bed is shown in Fig. 45, which gives the form of a carriage when designed to fit the ideal form of bed shown in Figs. 38 and 42. In this case

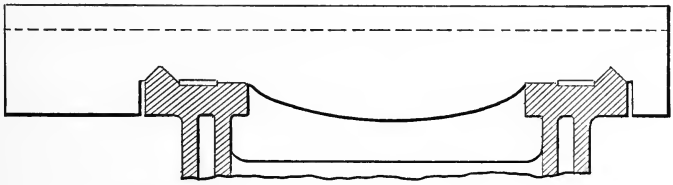


FIG. 45. — Form of Carriage for Ideal Form of Bed.

the full strength of the carriage is maintained and a second support is furnished it inside of the outer V at the front and back by the contact of flat, horizontal surfaces in the place where the inside V would be in the form of bed having four V's. This construction shortens very much the "span" of the carriage between supports and consequently renders it much more stiff and rigid,

adapting it to much more severe strains in heavy work than either style of carriage preceding it. In fact it is the strongest carriage now known, in proportion to its weight.

The form and proportions of the lathe bed having been duly considered, its different component parts illustrated and described, and these detail matters criticised and commented upon, the next part of the lathe to be dealt with would naturally seem to be the legs, cabinets, or like supports upon which the bed is to rest.

The usual height of the centers of a lathe from the floor is about 43 inches, and in designing lathes this height is maintained without regard to the capacity or swing of the lathe until its swing becomes so large that with the bed resting on a properly built foundation on a level with the floor, it becomes necessary to raise this height

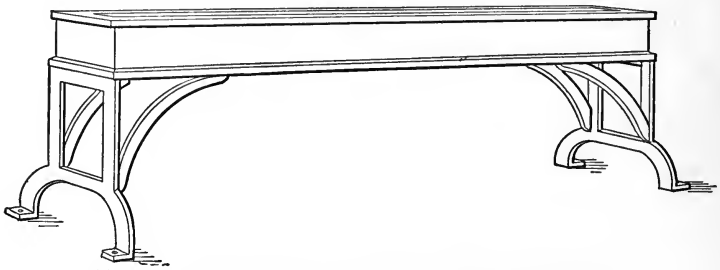


FIG. 46. — Early Form of Cast Iron Legs with Braces.

sufficiently to obtain a bed of proper depth and a head-stock of sufficient swing to meet the requirements.

Therefore the smaller the capacity of the lathe the higher will be the legs or other supports under the bed.

In the early style of wooden beds, these supports were simply legs of square timber bolted to the bed and either vertical or spread out at the floor, according to the notion of the builder. When cast iron beds came to be used the legs were also of cast iron and of rather frail design. Later, when the necessity for more rigidity was found desirable, not only the beds but their supporting legs were made heavier.

In a shop near Boston was found a lathe provided with an example of the earlier form of cast iron legs strengthened by cast iron braces as shown at A, A, A, A, Fig. 46. The lathe was 12-inch swing and of the hand lathe pattern, with a wooden cone pulley

on the spindle, probably built about 1840. The legs were quite light, the different members being about $\frac{3}{4}$ inch thick and 2 inches wide. The braces were of the same dimensions and secured at the ends by $\frac{1}{2}$-inch "tap bolts" of the old square-head style, the ends of the braces being thickened somewhat to accommodate them.

How this lathe happened to endure the wear and tear of shop use for so many years without the legs being broken is a mystery. Their frail and slender appearance beside the modern deep bed, supported by heavy cabinet legs, is an object lesson in the practical evolution of the American lathe.

With the continually increasing weight and rigidity of the lathe beds to meet the hard service of modern shop methods and high-speed steels, first represented by the Mushet tool steel, it became necessary to furnish much better supports for the lathe beds, and the fact was apparent that these supports must extend for a greater distance along the length of the bed than the older form of legs ever had. At this time there were several of the different machine tools supported on a "cupboard base," or a base of rectangular form having a door giving access to its interior for the purpose of stowing away tools, change-gears, wrenches, and like articles. This form of base was prominently used in the Universal Milling Machine. Whether the "cabinets" for supporting a lathe bed were suggested by this use of them or not does not appear, although it seems probable. We know that wooden cupboards had been used under lathes, being fastened to the legs and used for the same purposes as the cabinets or cupboards formed in the bases or, as sometimes called, the "standards" or columns of the later machines.

At the present time a number of lathe builders still use the old-style legs, made heavier and with the material better distributed for strength, and, as a rule, the top portion of the leg extending farther along on the under side of the bed for the purpose of giving better support.

It is also the case that the cabinet form of bed supports is used more upon expensive lathes, such, for instance, as those designed more particularly for tool room and precision work. For turret lathes and screw machines they are also much used, and are often cast as an integral portion of the bed itself instead of being made as a separate piece and bolted on.

Cabinet supports for lathe beds are made in various forms by the several builders, some of which will be illustrated in this chapter. These will be such as have some general features common to nearly all of them, and in addition a few of the forms having special features.

The correct principle governing the dimensions of cabinet supports should be properly understood. Obviously, the reasons for substituting cabinets for the earlier form of legs was to obtain a better support. It was certainly possible to so design the leg as to amply support the weight of the lathe and all that could be put upon it by way of work to be done by it. The disadvantage was that a leg placed at each end of the bed and extending only a short distance along under it left a long stretch of bed with no

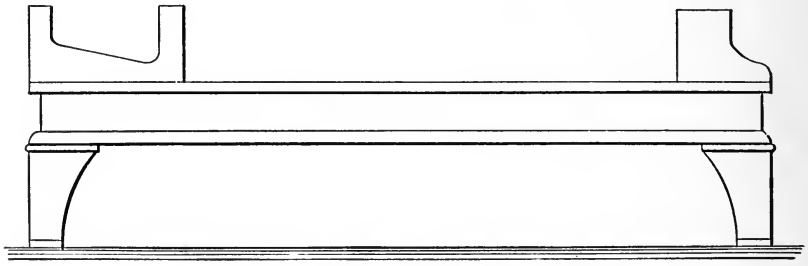


Fig. 47. — Lathe Bed Supported by Old Style Legs.

support at all. This necessitated "center legs" and, in a long lathe, two or three of them. Under these conditions it was a difficult matter to so set up a lathe that these center legs should all sit level and support the bed in a correct, level, straight line.

These difficulties are in a great measure avoided in the lathes provided with cabinet supports. In Fig. 47 the effect of the old-style legs is seen. Attention is called to the fact that the head-stock is only supported by the leg at the outer end, while the point at the front journal where the heaviest weight comes has no support whatever from the leg. The same may be said in a lesser degree of the rear end, where the tail-stock has only partial support in a similar manner. And when the tail-stock is moved out of its extreme rear position the case is much worse and identical with that of the head-stock. This condition will, of course, necessitate the use of a center leg, which if not supported upon the floor or

foundation in a perfectly correct position will do as much harm as good. If it is too low it will be of no benefit since the center of the bed may sink under the weight, and strain of the work upon the carriage. If it is too high the lathe will be thrown out of line.

In sharp contrast to these conditions is the bed shown in Fig. 48. In this case the front cabinet is of a length on the bed equal to the length of the head-stock, hence the front bearing of the head spindle has a support of solid iron down to the foundation, or floor upon which the cabinet supports rest. The tail-stock is similarly supported by a cabinet occupying the distance equal to its length upon the bed. An argument in favor of this method of supporting the bed is not necessary as the conditions are self-evident.

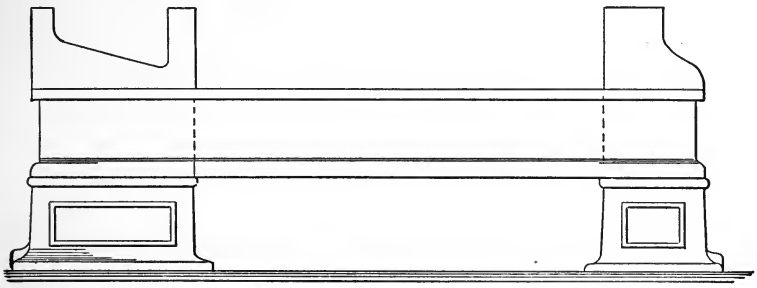


Fig. 48. — Form and Proportions of Cabinet Supports.

But there is still another reason why the cabinet support is the more rigid, and that is the fact that with the long distance on the bed to which the cabinet is firmly and solidly bolted comes additional stiffness and rigidity, not only in a vertical direction for sustaining weights, but also to withstand the torsional strains to which every lathe bed is subjected, and which are multiplied rapidly as we load the lathe with heavier work, take heavier cuts, and use high-speed tool steel, by which much greater speed may be used.

The next matter to be considered is the form of the cabinet, although this is a secondary consideration, the first being that we have the cabinet and that it reaches out under the bed to the practical length as shown in Fig. 48.

For small lathes, say from 12 to 20-inch swing, the cabinet is frequently made nearly square While this is wrong in theory, as has just been explained, it is an improvement upon the old-style

leg. The form shown in Fig. 48 is substantially that used by Lodge & Shipley in their smaller lathe. Its peculiar feature is the strength, vertical end walls, without projections at the base, while the regular projection is made in the front and the rear. This form is less expensive in its pattern work and somewhat easier to mold, but its appearance is not as good as the one shown in Fig. 50

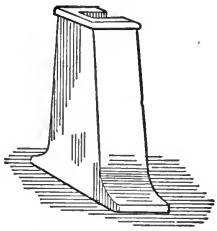


FIG. 49. — The Lodge & Shipley Cabinet for Small Lathes.

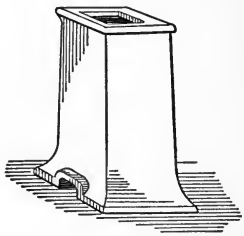


FIG. 50. — Ideal Form of Small Lathe Cabinet.

which has equal projections on all four sides and at the top and bottom, thus giving it a more symmetrical appearance. It may have only three sides enclosed, the side walls turning the corner for only an inch or so, and this side be placed underneath the lathe bed, as is now done by some of the builders. But as this cut-away portion would come directly under that point of the head-stock where the most support is needed, it is of doubtful utility to cut it away, or to reduce the support of solid iron at this point.

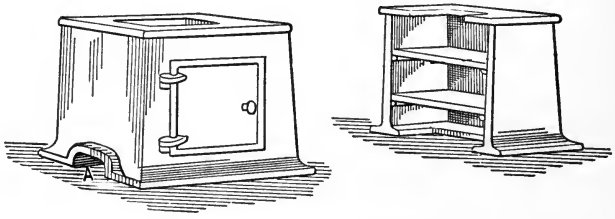


FIG. 51. — Cabinet and Cupboard.

Lathes for light work, of 12 to 18-inch swing, may be supported by square cabinets, but if for heavy duty and continuous hard work the cabinets should be considerably longer than they are wide and support the bed as shown in Fig. 47.

In Fig. 51 is shown a form for head and tail cabinets, or "Cabinet

and Cupboard," for medium-sized lathes, say from 20 to 28-inch swing. These answer the conditions as represented in Fig. 48, and are not excessively expensive. They also furnish one closed cabinet and an open cupboard, both of which are available for storing tools, gears, and similar articles. The arched opening at A affords a

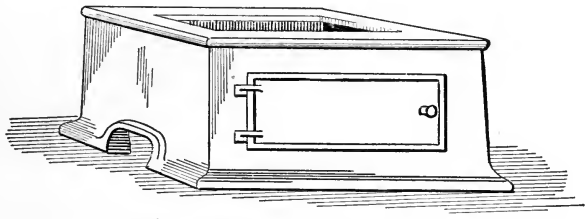


FIG. 52. — The Lodge & Shipley Form of Cabinet for Large Lathes.

convenient space for introducing a lever or bar for the purpose of moving the lathe. This arch should be placed in the cabinets of all but the smallest ones, and even in them a small arch suitable for the use of a crowbar will be found convenient.

In either of the styles of cabinets shown the shelves may be cast in, but the usual method is to cast strips upon which the ends of wooden shelves may rest, thus making not only the pattern work but the foundry work more simple and economical.

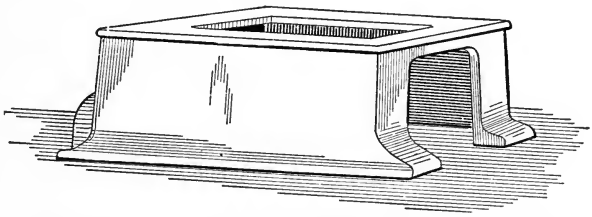


FIG. 53. — The Hendey-Norton Form of Cabinet for Large Lathes.

In Fig. 52 is shown the form of cabinet used by Lodge & Shipley for large lathes and which gives an excellent support to the bed and its superstructure.

In Fig. 53 is shown a similar cabinet used by the Hendey-Norton Company, differing from the last one in having the inner end cut away. This cabinet does not, of course, admit of the introduction

of shelves. In the larger lathe, say from 30 to 40-inch swing, inclusive, doors are not usually provided, as the height does not admit of it. Above 40-inch swing the bed usually rests directly upon the foundation.

The cabinets here shown are given simply as examples, but they give a good idea of the forms used by most of the modern lathe builders at the present time, and the reasons for their continued and enlarged use. It is altogether probable that the future will witness an increase rather than a decrease in the use of the cabinet for supporting machines of all kinds where it is possible to introduce them, on account of their great rigidity in proportion to the weight of cast iron used, as well as the fact that they furnish a safe and convenient receptacle for tools.

CHAPTER V

LATHE DESIGN; THE HEAD-STOCK CASTING, THE SPINDLE AND THE SPINDLE CONE

Design of head-stock for wooden bed lathes. Early design for use on a cast iron bed. An old New Haven head-stock. The arch form of the bottom plate. Providing for reversing gears. The Hendey-Norton head-stock. The Schumacher & Boye head-stock. The Le Blond head-stock. The New Haven head-stock. The arch tie brace of the new Hendey-Norton design. Generalities in describing a lathe spindle. Designing a spindle. Governing conditions. The nose of the spindle. Spindle collars. Proper proportions for lathe spindles. Large *versus* long bearings. Design of the spindle cone.

THE subject of lathe design is continued by the consideration of the design and construction of the head-stock, which in some respects is the most important part, and with it and the parts which go to make up the complete head-stock, the most important group of parts in the lathe.

In the earlier form of lathes this piece was, like most of the other parts, simple and crude in design as well as in the workmanship bestowed upon it. It generally consisted of a base and the two upright ends in which provision was made to receive the boxes, and when wooden beds were thought sufficient for a lathe a strip was added beneath that filled the space between the two timbers forming the bed. Such a design for a head-stock is shown in Fig. 53, which is taken from an old lathe that did many years' service in a general repair shop. It will be noticed that the housing for the spindle boxes do not have square edges, but are of V-shaped form. They were finished with a file only and the boxes made of cast iron, filed to a fit and lined with babbitt metal which was said to have been poured around the lathe spindle after it was finished, set in place, and lined up as well as might be with the crude appliances

at hand. The top portion of the boxes were held down by a straight bar cap with two holes which fitted over fixed threaded studs that had been cast into the head-stock for this purpose.

The lathe was devoid of a back gear and the spindle carried a three-step cone, the largest part of which was as large as was possible to get into the head, and a belt quite wide, considering the power then thought necessary to drive a lathe carrying the diminutive chip which was considered proper for a lathe to take at the time this lathe was in use.

Later on, when the cast iron bed was adopted and when back gears were added to the lathe, the requirements of additional strength were recognized and not only the base plate, but the up-

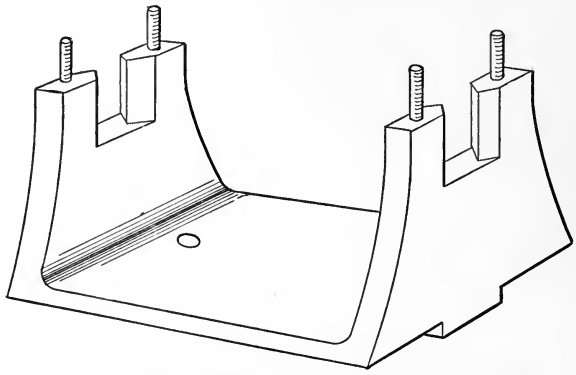


FIG. 54. — Early Form of Head-Stock for Wooden Lathe Bed.

rights or housings at the front and rear end, were made thicker and heavier. One of these head-stocks is shown in Fig. 54, which gives a good general idea of the form of the casting and shows also a strengthening brace A. While it would seem at first thought more necessary to brace the housing of the front box than that carrying the rear journal, it should be remembered that the latter must withstand the strain of the "thrust" or endwise pressure of the spindle due to holding work upon centers, and the pressure of drilling work, one end of which is held in a chuck and the other in a center rest, and similar kinds of work. While in the modern lathes this thrust device is usually a part of the rear box, the earlier method was to fix two studs in the rear of the head-stock, one in

each side of the rear box and on a horizontal line with it, and across these to fix a strong bar carrying an adjustable thrust screw for taking the end thrust of the spindle. The details and design of this important device will be taken up further on.

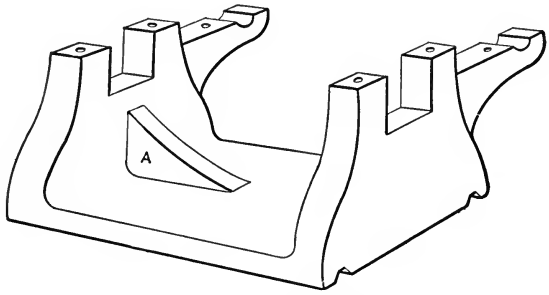


Fig. 55. — A Later Form of Head-Stock with Back Gears and a Strengthening Brace.

In Fig. 55 is shown a peculiar form of head-stock upon an old lathe in one of the older shops in New Haven, Conn. The lathe was broken up for old iron after an indefinite period of idleness. It was of about 16-inch swing and the various members of the head-stock were about one and one-half inches square. The bed of the lathe, and the legs which supported it, were of cast iron and very much like those shown in Fig. 46. The head was provided with back gears of very light design and the lathe had a lead screw and

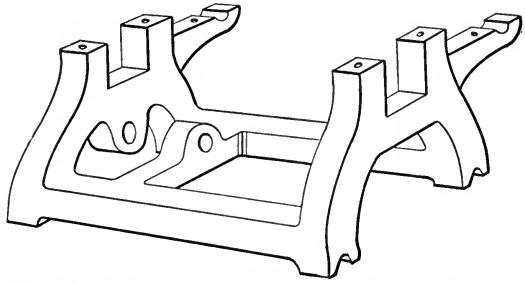


Fig. 56. — Form of Head-Stock on Old Lathe found in New Haven, Conn.

feed-rod adapting it for thread cutting. It was undoubtedly considered a proper engine lathe "in its day."

The next form of head-stock which followed that shown in Fig. 54 seems to have been of the form shown in Fig. 56. In this case

the base of the casting was raised in arch-like form and the under side recessed to the same form so as to maintain an equal thickness of metal throughout. This form seems to have been a favorite one and many lathes were built by various makers with substantially this form, the variations from it not being of sufficient importance to justify a further classification.

As yet the housings had not been made thick enough to suggest coring them out in order to save iron or for the purpose of avoiding unequal contraction of the metal upon cooling after casting, by making all members of the casting of as nearly an equal thickness as possible. Of late years these points have received much attention and study by the designers of machine tools, and rightly

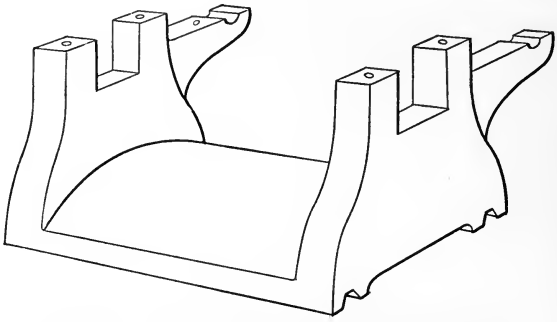


FIG. 57. — One of the Older Favorite Forms of Head-Stock.

so, as their importance was to a large extent overlooked in the earlier designs, the reason probably being that all castings were made so much lighter and had much less strain to withstand in the regular service to which the machine was put.

In Fig. 57 is shown a modification of the arch form shown in Fig. 56, which has for its purpose the strengthening obtained by the rib A in Fig. 54, only in a better form, as the method is "cored out," or formed with a "green sand core" under the head-stock, so as to provide for an equal thickness of metal over the entire base. This raised portion could be introduced quite conveniently as the small end of the spindle cone was located over it, thus insuring ample space for building it up.

In the examples thus far shown of lathe heads the feed gears

were located outside the housings, except in the case of that shown in Fig. 55. As the change came to be made of locating "tumbler gears," or reversing gears, inside of the housing, it naturally followed that the metal of the head-stock base must be cut away under that part of the main spindle upon which was fixed the spindle gear or feed gear from which the feed mechanism was driven. This was the case for perhaps fifty years, and at the present time, now that reversing devices are constructed as a part of the apron mechanism, the feed gears may be placed outside of the housing, although some good builders still keep it inside and connected in practically "the same old way," even if the "yoke gears" or reversing gears are omitted.

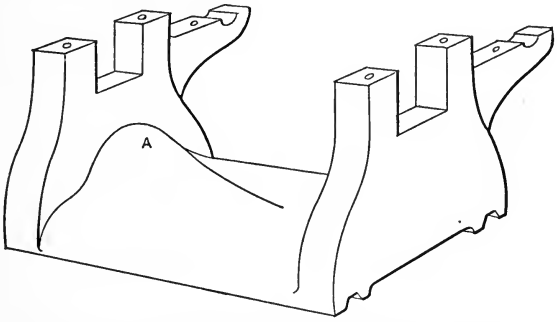


FIG. 58. — Another Form of Strengthening Brace.

When reversing gears were thought necessary to be upon the inside of the housing, a hole was cut out for them in the raised arch A, Fig. 57, and this practice was followed in any head-stock having this or a similar obstruction to these gears, and provided, of course, that they were to be located inside of the rear housing.

One of the recent modifications of the above form is that shown in Fig. 58, which is a type of the Hendey-Norton manufacture. The central figure is a front elevation with the sectional form indicated by dotted lines. The figure at the left is a rear end elevation with the internal form on the line A, A, of the central figure, while the figure on the right is a similar elevation of the front end with dotted lines showing the section on the line B, B.

It will be seen that the portion of the base on the line A, A, is of arched form, somewhat as shown at A, Fig. 57, while the form at

the line B, B, is of an inverted arch, or as frequently called by the shop men a "pig trough" shape. This latter form enables the metal to be carried higher up at the front and back while the center is depressed to give proper clearance for the larger steps of the cone and the face gear. At the lowest part of this depression there is usually an opening through which oil may drip so as not to collect inconveniently at this point. The arch-like form near the rear housing adds very much to the strength and rigidity of the casting. It will be noticed that in this design the main spindle boxes are not "capped in," that is, held down by removable caps. More will be said of this peculiarity in describing boxes and spindles.

The cores beneath the base are carried up into the housings in many of the modern head-stocks as far as possible, and still leave ample support for the boxes and spindles. The advisability of

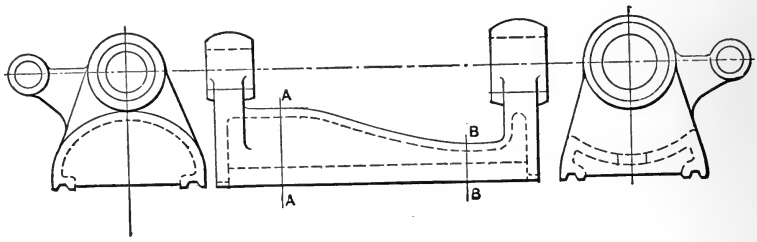


Fig. 59. — The Hendey-Norton Form of Head-Stock.

this method of lightening the weight of the casting is still an open question among machine tool designers who have endeavored to avoid unequal strains in the shrinkage of castings by making all members of as nearly equal thickness as possible. Sometimes this idea is carried too far and the result is liable to be that of sacrificing the necessary rigidity to prevent vibration, in the effort to follow out the ideal as to strains.

Fig. 59 shows a head-stock in which the inverted arch form is continued the entire length between the housings, but is carried upon a curved line as shown and forms a very graceful curve. The three figures are arranged the same as those comprising Fig. 58. The height of the curve might be greater at the line A, A, as will be shown in some others further on in this chapter, and the strength of the casting considerably increased.

This form is used with few modifications to adapt it to the diameters of driving-cones, the nature of the back gears and the feed gears and similar conditions that tend to somewhat alter the construction outlines of its design. This form seems to be a favorite one with designers, since among all the different builders and the variety of designs there are more builders using this form than all the others put together.

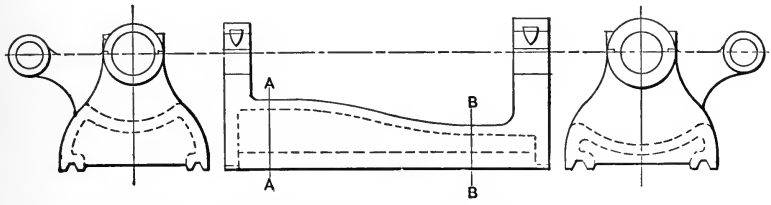


FIG. 60. — Form of Head-Stock built by a Majority of Lathe Builders.

While the above form of design carries a reversed curve for the top of the base, the form used by Shumacher and Boye, shown in Fig. 60, is of a single curve from rear to front housing and the inverted arch in its transverse sectional form. In this design the front and back is carried high up near the rear housing and comparatively low down near the front housing.

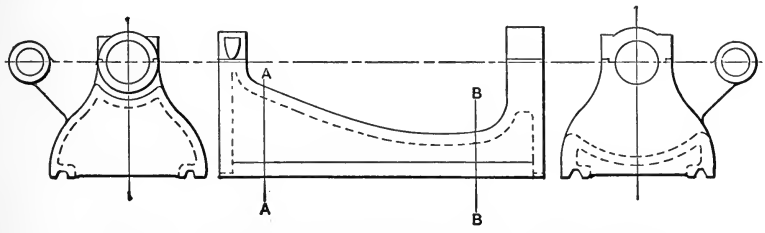


FIG. 61. — The Schumacher & Boyce Form of Head-Stock.

This is a design of much strength and rigidity in proportion to the weight of the casting, the metal being well distributed to resist heavy strains in the operation of the lathe.

The Le Blond type is shown in Fig. 61. In this we have a straight line at the back and front, with a modification of the reversed curve and the combination of the arch proper and the inverted arch as shown in Fig. 58. The form is pleasing to the eye,

and the strength of the casting is quite sufficient for the requirements. In this case the housings are made of ample width, especially the front one. They are cored out inside so as to have substantially an equal thickness of metal at nearly all parts.

The New Haven type of head-stock is shown in Fig. 62. In

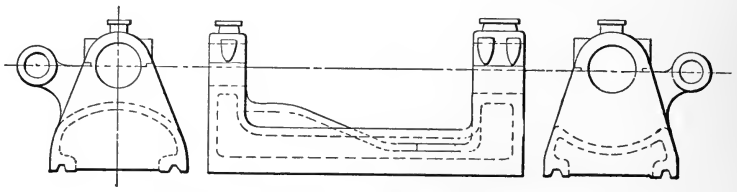


FIG. 62. — The Le Blond Form of Head-Stock.

this case the inverted arch is used all the way through, but it is upon straight lines, that form a cross section at A, A, continuing straight and on a proper incline to a point near the line B, B, from whence it is horizontal.

This design gives great strength, and with the proper proportions and thickness of metal throughout it is as rigid as it is possible to design a head-stock. The housings are unusually thick and cored out underneath as shown by dotted lines.

The design shown in Fig. 63 is by Hendey-Norton, and is prac-

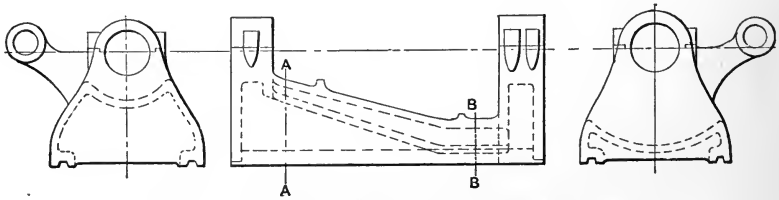


FIG. 63. — The New Haven Form of Head-Stock.

tically the same as that shown in Fig. 58, except for the arched brace C, from the front to the rear housing, effectually tying them together and thus adding considerably to the rigidity of the spindle-bearing boxes, which is always an excellent point to be considered.

The fact that these housings are solid, that is, not held by separate caps, permits the addition of this very strong brace, which could

not be efficiently added to a head-stock whose boxes are held in by a separate cap.

While this idea is now quite common in the design of milling machines, it has not been applied to the head-stocks of lathes by any builders but these so far as is known.

There are many classes of work in which a head-stock so braced would be very valuable, as its strength and rigidity is much increased by it and the strain and vibration is considerably reduced, which has the effect of increasing the efficiency and also the life of the cutting-tools. This question of increased rigidity and the importance of obtaining it has received much attention in the past few years, and the result has been the constant increase in the pro-

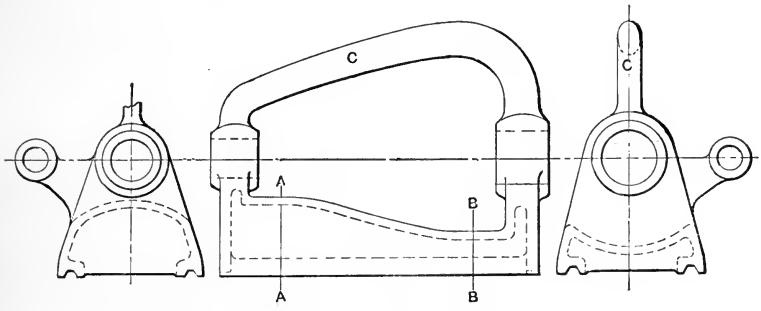


FIG. 64. — Special Form of Hendey-Norton Head-Stock.

portions and the weights of all parts of metal-working machinery which form the supports of cutting-tools or their intermediary parts. It is altogether probable that in this increase in weight the limit has not been reached, but that it will continue in years to come, although not perhaps in the same proportion that it has during the last decade. The use of high-speed steel will, doubtless, be extended to other uses than at present, and its price will be materially reduced, thus increasing the amount used and consequently demanding stronger machines and more power to drive them, so as to continually reduce the cost of the product by reducing the time of machine operations.

Having designed a good head-stock with ample proportions in general, the metal so distributed as to withstand not only the strains to which it will be subjected in performing its appointed

functions, but with proper considerations for the changes which will take place in the process of casting and cooling, and not forgetting that castings will change their form more or less for weeks after being cast, our next concern will be the spindle.

It is not enough to say, as catalogues sometimes do, that "the spindle is of hammered crucible steel of large diameter and runs in hard bronze boxes." This may all be relatively true and yet it may be neither properly designed or properly constructed for the uses to which it is to be put.

To design a lathe spindle we must consider the work it has to do, the points at which it will be supported, the points where it must support the material that is to be machined, and the parts with

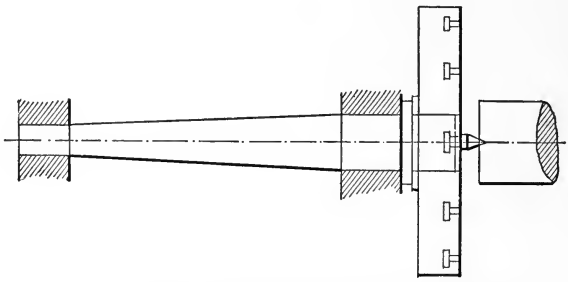


FIG. 65. — Lathe Spindle showing Principal Weight on Front Bearing.

which it is loaded and which become a part of its attendant mechanism; not only these points, but others that are equally important,— the torsional strains to which it will be subjected in performing its regular functions, and which include that of driving the piece to be turned, of the strains of the cone when driving direct, or the back gears or triple gears when they are in action, and of the feeding mechanism which derives its motion from the rear end of the spindle.

If we are to consider principally the weight of the face-plate and the material to be turned, which falls almost entirely upon the front journal, we should have the form of the lathe spindle as represented in Fig. 65. In this case the front bearing would necessarily be very large and strong and with ample support. The rear bearing need not be a matter of serious consideration, as it is quite a

distance from the front bearing, while the weight of the face-plate or chuck carrying the work, or the center which supports one end of the work, if supported by this means, carries nearly all the strain. Therefore the rear bearing may be small and short as shown.

Again, if the weight of the cone and its parts are to be principally considered, we should have a spindle more nearly conforming to the outline shown in Fig. 66, the rear bearing being larger and the front bearing smaller than is shown in Fig. 65. This would also be the case if the upward pull of the belt were a governing factor in determining the form and proportion of the spindle. But the fact is that the cone and its action upon the spindle, so far as its weight or the belt pull upon the spindle, while in reality a factor

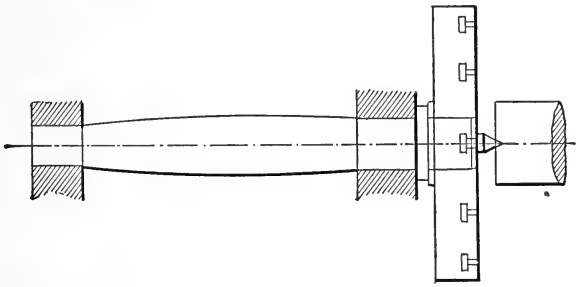


Fig. 66. — Form of Lathe Spindle when undue prominence is given to Cone Pulley.

to be considered, as will be referred to later on, is not the prime factor by any means. Therefore we must recur to the form shown in Fig. 65 for the points necessary for the proper consideration of forms, the determination of the contour, and the proper proportions of the lathe spindle.

This view of the case leads us to the choice of a medium between the two extremes presented and an ideal form as shown in Fig. 67, wherein the conditions governing both the former examples are properly considered and met.

There is one more condition to be considered, however. This is the upward or lifting tendency supposed to exist by reason of the cutting-tool forming a fulcrum, which, in connection with the circular motion of the piece being turned, tends to lift the spindle in the front box and so throws an upward strain on the cap over the

front journal. This tendency is represented in Fig. 68, wherein the arrow shows the direction of the belt and revolution of the material being turned. It is doubtful, however, if this point is of much importance, particularly in a lathe properly designed as to the dimensions and weights of its parts, especially of the spindle and its appendages.

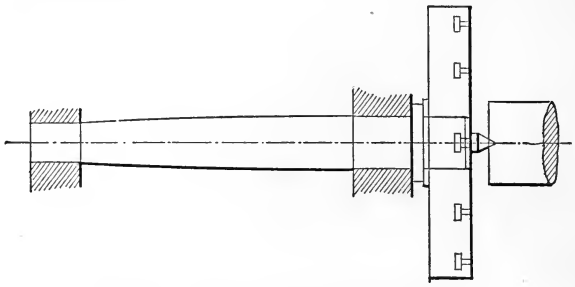


Fig. 67. — Ideal Form of Lathe Spindle.

Taking all these matters into consideration we shall find that the proper proportion and design of the spindle with the face gear, cone pinion, and the feed gear, will be substantially as shown in Fig. 68, leaving out of the design for the time being the special

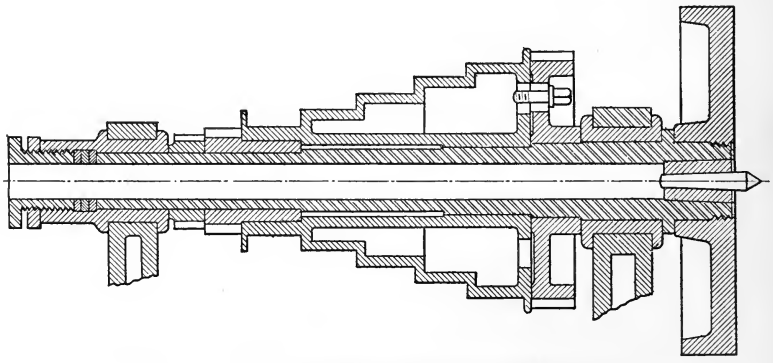


Fig. 68. — The Ideal Spindle shown in Practical Form.

form of journal oiling devices, the thrust bearing for the rear end and the special form of the nose of the spindle, which will next receive attention.

As to the nose of the spindle. It is customary by many builders to cut the thread on the nose of the spindle nearly up to the collar,

against which the chuck-plate or the face-plate takes its bearing. It is a well-known fact that it is extremely difficult to accurately center such a plate upon a threaded portion of a spindle. As the purpose of the thread is simply to prevent the plate from coming off the spindle, it naturally follows that the length of this thread may be very much reduced without in any way reducing its capacity to securely hold the plate in place. It is also quite as evident that we can hold the plate perfectly true in its place and exactly concentric with the front bearing if we grind a portion of the nose of the spindle to a truly cylindrical form when we grind the front bearing and then fit a sufficient portion of the bore in the plate to this ground surface. This may be accomplished by threading the nose of the spindle through only one third of its length, and grinding the remaining two thirds to which the chuck-plate or face-plate is fitted. This centers the plate accurately with the axis of the spindle. If the face of the collar is accurately ground, and the hub of the chuck-plate or face-plate fits fairly against it, there will be no difficulty when removing the plate of always being able to replace it in exactly its former position, perfectly true in the running of its face and perfectly concentric with the ground bearings of the spindle. Even the wearing of the thread will not effect its true running, since the only office of the thread is to hold it on, while the ground surfaces insure its trueness. This is shown in Fig. 69.

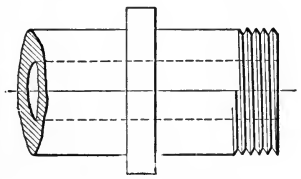


Fig. 69. — Nose of Spindle.

In this connection it is noticeable that some manufactures omit the large collar on the front end of the spindle and furnish only a small shoulder on the spindle, due to the nose being somewhat smaller than the front bearing, against which the face-plate or chuck-plate rests, and assuming that its close fit upon the ground surface between this shoulder and the threaded portion will be quite sufficient for all purposes. This would seem to be an erroneous view of the question as this comparatively small shoulder cannot possibly afford the support and rigidity that may be obtained by a collar or thrust surface of two or three times the area. It is true that as a matter of economy in furnishing the stock for these spindles the question favors the omission of the shoulder. But

as a matter of good design and proper shop practice it will hardly be disputed that the larger collar, forged on, is the proper design and construction.

Referring again to Fig. 68, there are several points to which it is proper to call attention. The spindle boxes represented are of bronze and such as are now commonly used in good lathes. The formation of the front end of the spindle with its fixed collar formed in the forging is also the usual practice, except in some of the lathes of newest design and development, in which it is probably omitted as being considered an unnecessary expense. The thrust bearing is similar to that represented in Fig. 74, but an improvement upon it, since a hardened steel ring is interposed between two bronze rings, which render cutting well-nigh impossible.

The cone pinion is made of machine steel and has a long sleeve forced into the small end of the spindle cone. While it is not good practice to run two steel surfaces together unless one is hardened, it is still perfectly practicable in this case as the pinion is of ordinary soft machine steel while the spindle is 50 to 60-point carbon crucible steel, which answers the conditions in practice and many lathes are now built in this manner.

The spindle is shown bored out, as a large majority of lathes are now so constructed and the demands of the customers require hollow spindles in nearly every instance when the lathe is over 12-inch swing.

The proportions upon which this design is made may be interesting. Using the full swing of the lathe in inches as a unit, represented by A, the proportions of the spindle will be as follows:

Diameter of the front bearing, $A \div 5.7''$
Length of the front bearing, $A \div 3.6''$
Diameter of the rear bearing, $A \div 6''$
Length of the rear bearing, $A \div 4.5''$
Length of the nose of the spindle, $A \div 6''$
Distance between bearings, $A \times 1.2''$
Diameter of bore through spindle, $A \div 10''$

In Fig. 70 we have a spindle of somewhat overgrown proportions, yet one of proportions advocated by an eminently practical mechanic who is said to have remarked that he "didn't want a lathe spindle with a front bearing so many inches diameter and so

many inches long, but he wanted it with a bearing so many inches *large* and so many inches *short*," by which we may readily understand his idea that a *large* and *short* front bearing was much better adapted to the work than one of medium diameter and extra length.

Thus if we have a front bearing of $3\frac{1}{4}$ inches diameter and 5 inches long, and we increase the diameter 50 per cent and reduce the length in the same proportion, viz., one third, we shall have about the same area of bearing surface, but we shall gain the advantage of bringing the driving-cone closer to the work, of shortening the whole length of the spindle, and of making the front end of the spindle much more rigid and better adapted to withstand the strain of a heavy cut on work of the usual diameters, and still

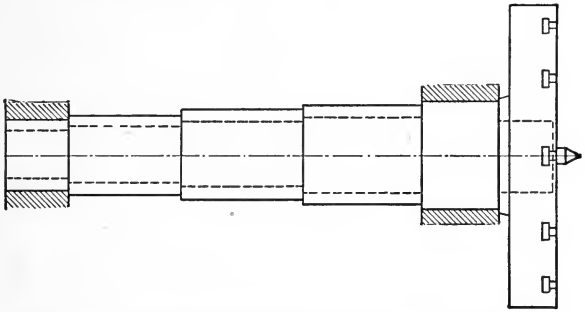


Fig. 70. — Lathe Spindle with Extra Large Bearings.

better when large facing work is to be done and the cut is carried out near the periphery of the largest diameter that can be handled.

It does not follow, however, that the proportions of the enlarged diameter of the front bearing need be carried all the way through, by which a spindle of unnecessary weight would be produced, as practically all important advantages may be gained if its dimensions are as shown in dotted lines in the engraving.

In Fig. 71 is shown the opposite method of designing a lathe spindle, that is, by making the bearings of the usual diameter, but increasing the length to a considerable extent. It is evident that while there are always certain advantages in increasing the distance between the supporting boxes, there is an apparent tendency to weakness, or lack of rigidity of the spindle at the vital point, namely, the overhanging portion of the front end of the spindle

which supports the face-plate, the chuck, or the work as it bears upon the lathe center.

As between the two designs of extra *large* bearings and extra *long* bearings, the practical advantages seem to be in favor of the former.

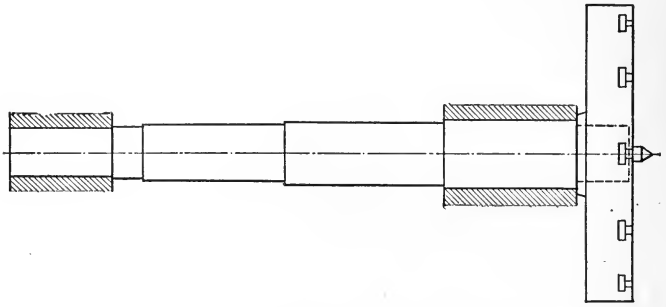


Fig. 71. — Lathe Spindle with Extra Long Bearings.

The spindle cone should receive due attention. The method of introducing the cone gear sleeve into the small end of the cone has been referred to in connection with Fig. 68. The large end of the cone may have an inwardly projecting flange cast integral with it or made separate and attached by screws. In either case the locking bolt must be accommodated in it. Between this head and its bearing it should be well supported from the central quill. This may be done by providing for four or more radial plates extending from the connection with the central quill under the smallest step to one half the remaining distance toward the large end of the cone, as shown in Fig. 68.

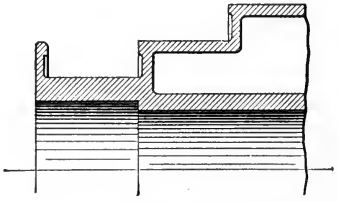


Fig. 72. — Form of Cone Steps.

In finishing the outside of the cone the rising steps should be faced up as shown in Fig. 72, that is, with the face cut back from $\frac{1}{32}$ to $\frac{1}{16}$ of an inch, according to the size of the cone, for the pur-

pose of lessening the friction on the edge of the belt. In cases where this relief is not given to the belt it is not an unusual condition to find the edges of belts running over cones, particularly at high speeds, to be turned up, the corners where the belt is joined to be distorted or worn away, and in a short time the belt well-nigh ruined.

In purchasing lathes or other machines provided with speed cones, the purchaser should insist that the faces of the cones should be made as shown, as it is a matter of much importance in belt economy and belt efficiency.

CHAPTER VI

LATHE DESIGN: THE SPINDLE BEARINGS, THE BACK GEARS, AND THE TRIPLE GEAR MECHANISM

Designing spindle bearings and boxes. Thrust bearings. The Lodge & Shipley form. Ball bearings. Proper metal for boxes. The cast iron box. Early form of boxes. The cylindrical form. Thrust bearings for a light lathe. Experiments with different metals on high speeds. Curved journals. The involute curve. The Schiele curve. Conical bearings. Adjustments to take up wear. Split boxes. Line-reaming boxes. Lubrication of spindle bearings. The plain brass oil cup. The use of a wick. Oil reservoirs. Loose ring oilers. Chain oilers. Lodge & Shipley oil rings. Neglect of proper lubrication. Back gearing. Varying the spindle speeds. Triple gearing. Theory of back gearing. Back gear calculations. Triple gear calculations. Diagram of spindle speeds. Faulty designing of back gears and triple gears. Four examples. A 14-inch swing lathe. A 19-inch swing lathe. A 17-inch swing lathe. A 30-inch swing triple-geared lathe. Explanation of the back gear diagrams. Essential parts of the triple gear mechanism. "Guesswork" in lathe designing. Wasted opportunities. Designing the head-stock. Cone diameters. A homely proportion. The modern tendency in cone design. Proportions of back gears. Driving the feeding mechanism. Reversing the feed. Variable feed devices. Rapid change gear devices.

GREAT care ought always to be used in the design of the bearings of the spindle and the boxes in which they run. To a great extent these determine the life and usefulness of the lathe, for with an improperly made spindle or poor boxes, either of design or quality of material, the lathe is soon worn so much out of true as to be practically worthless.

Mention has been made of the thrust bearing at the rear box. It is important that this should be well designed and constructed, as the quality of the lathe's work, particularly face-plate and chuck work, depends upon its proper performance.

One form is shown in Fig. 73, which is a style used for a number

of years on the New Haven lathes. It consists of a hardened steel ring B, forced into an annular groove in the end of the hollow spindle A. The rear end of the bronze box C is extended as shown and tapped out with a fine thread. Fitted to this is the thrust sleeve D, whose forward end bears against the ring B. The sleeve D is adjusted by means of two slots (one of which is shown) cut across its face, and is held in position by the check-nut E. This device is much improved by the addition of a hard bronze ring, loosely interposed between the thrust sleeve D and the hardened ring B. The sleeve D was made of a steel casting, as was also the check-nut E, which had holes drilled around its circumference for the accommodation of a spanner for adjusting it. The device was very successful in practical use.

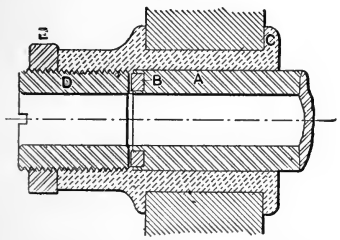


FIG. 73. — New Haven Lathe Thrust Bearing.

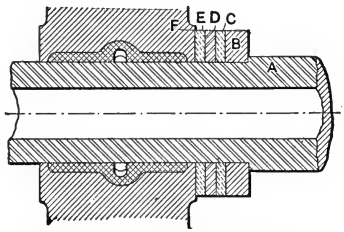


FIG. 74. — Lodge & Shipley Thrust Bearing.

The form of thrust bearing used on the Lodge & Shipley lathes is shown in Fig. 74, and is constructed as follows: Upon the spindle A is keyed the cast iron ring B. Next to this is a bronze washer C; next a hardened steel washer D; then another bronze washer E, which in turn rests against the faced end of the rear box F, which in this case is formed of the head-stock casting itself.

While this is an efficient form of end thrust it has the disadvantage of occupying some space inside the rear box and consequently increasing the distance between the front and rear boxes, increasing the length of the head-stock by just its own width, or the space occupied by the cast iron collar and the three friction washers. Unless covered by a projecting portion of the casting, or by a special guard over it, there will be more or less trouble on account of dirt working in between the washers. This, however, is easy to prevent by a proper design and construction.

The popularity of the ball bearing and its successful application to many different uses no doubt suggested it as a proper device for the thrust bearing of a lathe. It has been objected to in a lathe designed for fine work, on account of the possible influence of any slight vibration caused by the rapid rotation of the balls, owing to any inaccuracy in their perfect spherical shape or diameters. Yet the device is in apparently successful use on many lathes at this time. The construction is shown in Fig. 75. Upon the spindle A is fixed the collar B, having a ball-race cut in its rear side as shown. Fixed to the end of the box, or the inside of the rear housing, as the case may be, is the collar C, which also has a ball-race formed in it, and set deep enough to form a sleeve which projects out over the balls and the collar B, so as to protect the balls from dirt. This thrust is open to one of the objections urged against the form shown in Fig. 74, namely, the space it occupies on the lathe spindle.

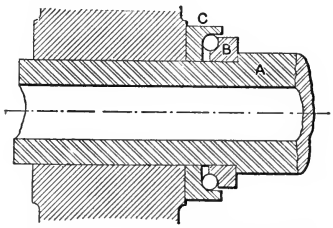


FIG. 75. — Ball Thrust Bearing.

It is entirely feasible, however, to place this device, or the one shown in Fig. 74, near the rear end, or even at the center of the rear box if so desired. In this location it would have the added advantage of position for ample lubrication and absolute protection from dirt.

There has been a great deal of discussion on the question of what is the proper metal, and what is the proper form for a lathe spindle box. Any number of different metals have been used for this purpose, from cast iron at a cost of two and one half cents per pound to a fine quality of nickel-bronze worth thirty one cents per pound.

It is an old and a true saying that with a good, true, and well finished journal, and the bearing kept free from dirt, always clean and well lubricated with good oil, a cast iron box is as good as anything that can be made. Every practical shop man of even moderate experience can cite instances of the excellent record of the old-time cast iron box, and the fact that it is still used by some of the oldest and best lathe manufacturers is certainly a strong

argument in its favor. But one condition is always insisted upon: it must be kept clean and free from dirt. It will not stand dirt. Under adverse conditions many bronze boxes withstand successfully dirt, grit, and poor lubrication that would put the cast iron box out of business in a few hours.

Of course it is assumed in all these remarks that the lathe spindles are made of 50 to 60-point crucible steel, and that they have been accurately ground, as this is the only method by which we can insure the perfect cylindrical form of the bearing that is so necessary to the successful operation of a lathe.

The older form of designing the housing of the head-stock for the reception of the boxes was to have the opening at the head and rear end of square form and covered by a straight bar of cast iron or machine steel, secured at the ends by hexagonal headed cap screws. Later on it was found more economical to make these spaces circular and to have them bored out with a boring bar, the boxes being fitted to the circular opening and capped down, when the inner surface of the box itself was bored out and hand reamed.

For small lathes, such as bench lathes and precision lathes, it is necessary to carefully exclude dirt as well as to have correct bearings, since a good, true bearing will not long remain so if exposed to dust and dirt or even to poor and dirty oil used as a lubricant.

In Fig. 76 is shown a thrust bearing for a light lathe that is provided with an adjustment on both the front and the rear side of the rear housing. This is done by providing the steel collars B, B, threaded to fit the spindle A, so as to allow adjustment at either end, and that one of these collars at each end shall act as a check-nut to the other, while the wear is taken by the loose bronze collars C, C, interposed between the steel collars and the face of the housing.

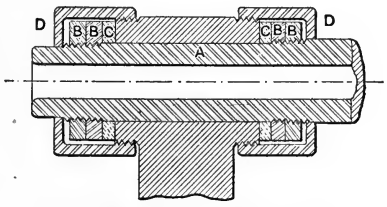


FIG. 76. — Rear Bearing for Small Lathe.

The faced sides of the housing project to the front and rear a short distance, and this projecting part is threaded and has fitted to it the dust-caps D, D, which may be made of steel, as shown,

but are frequently made of brass. They are bored to fit the spindle rather closely so as to more effectually exclude dirt. In some instances it may be advisable to place outside of the outer collar B a felt washer closely fitting the spindle, which will be an effectual means of insuring a clean bearing.

If the thrust on the spindle is considerable, it may be well to interpose two washers so as to decrease the friction, and for still heavier thrusts we have always recourse to the plan of using a steel washer with a bronze one on each side of it, which will in nearly every case be found sufficient even with a very heavy end pressure. In the case given in Fig. 76, it will be noticed that the spindle runs in a reamed hole in the cast iron of the head-stock itself. This has been so arranged purposely and forms a very good bearing when carefully protected from dirt. Such bearings may, of course, be lined with genuine babbitt metal or with brass, bronze, or any of the so-called "anti-friction metals."

In an extended series of experiments, the purpose of which was to ascertain the best materials for a shaft and a box running at high speeds, in this case 7000 to 8000 revolutions per minute, it was demonstrated that a hardened and ground tool steel spindle, running in a box of cast tin, bored, reamed, and scraped, would far outlast any of the dozen or more materials tested. The inner surface of the box soon took on a glaze that was nearly black and very glossy, and this was retained during over a year's wear to the author's personal knowledge, and probably much longer. In this series of experiments a steel shaft and steel box was ruined in less than an hour's run.

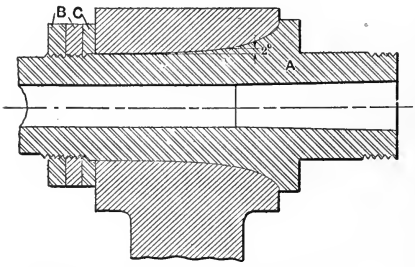


Fig. 77. — Involute Front Bearing.

Hitherto attention has been directed to straight or cylindrical bearings, that is, those of the same diameter at both ends. Where a very accurate bearing is required, and one that will stand a great amount of wear and still maintain its correct alignment, the involute bearing shown in Fig. 77 is the proper form. About one half the length of this bearing may be a

straight line, but conical, inclined two degrees from the axis. The remainder of the length has either an involute or elliptic form to a diameter 60 per cent larger than the small end of the bearing. The involute form is preferable, while the "Schiele curve" is, of course, the ideal contour. The spindle is held in place by the collars B, B, threaded upon the spindle A, and a bronze washer C, interposed to eliminate friction. While this is theoretically correct and entirely practicable, it is an expensive bearing to make and to fit up in small numbers, and when special tools are made for it they are expensive to maintain.

For these reasons there was designed a sort of compromise form which is shown in Fig. 78, and which is not subject to the disadvantages referred to above. The conical portion has an inclination of three degrees with the axis, and the angle at the large end is twenty degrees from a right angle with the axis. In practice it is much more economically made and fitted and answers all conditions nearly as well.

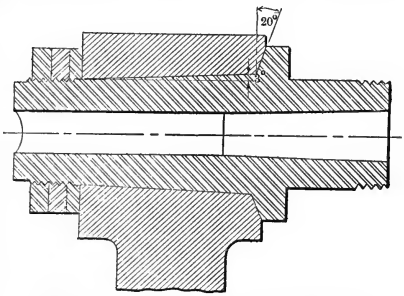


Fig. 78. — Conical Front Bearing.

The arrangements for taking up wear are the same as those shown in Fig. 77. In neither case is a thrust bearing required at the rear box. In some respects, particularly in small lathes, this is considered the better practice.

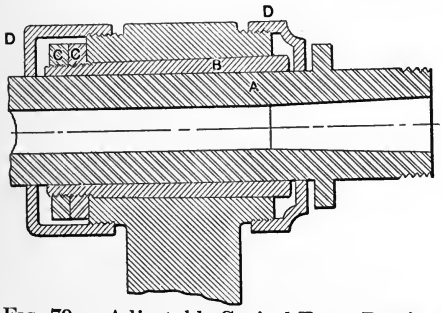


Fig. 79.—Adjustable Conical Front Bearing.

In Fig. 79 is shown another form of adjustable bearing which, like the designs shown in Figs. 77 and 78, has the very important advantage of always maintaining the correct alignment of the spindle. One of the difficulties of all spindles running in "split boxes" is that the lower half of the box wears more than the cap and consequently the

spindle is gradually but surely wearing lower. This is corrected by placing pieces of paper or very thin metal under the lower box. But as sufficient attention is seldom given to this point in keeping a lathe in proper condition, it is most unusual to find a lathe whose centers are in perfect alignment.

In the present case the spindle A is cylindrical, that is, with no taper, and runs in a hard bronze sleeve B, which has a taper of two degrees on each side and fits closely in the taper reamed hole in the head-stock housing. This bronze sleeve is split through its length and arranged to be drawn into the taper hole by means of two nuts C, C, threaded upon its small end. One of these nuts acts as a check-nut to the other. Therefore the bronze sleeve may always be drawn as tightly around the spindle bearing as may be desired, and effectually held in that position. As the compression is the same through the entire circumference, the spindle will retain its central position and correct alignment even after a very considerable amount of wear, and a new bronze sleeve may be readily fitted when the first one is worn out. This substitution is not only economical but the exact alignment is still preserved.

It may be argued that this sleeve, like the split box, will wear most at the bottom. This is perfectly correct, but an occasional turning of the sleeve through a quarter or a sixth of a revolution, effectually corrects this tendency.

As shown in Fig. 79, this bearing is protected by dust-caps or rings D, D, which may still further be reinforced by the introduction of felt washers.

However these bearings are made and whatever care may be exercised in machining and fitting the boxes or in securing a correct alignment of the circular or square receptacles in the housings for receiving the boxes, it will be found generally necessary and always safe and advisable to "line-ream" the boxes after they are in place and securely clamped. This is done by fixing very carefully ground shell reamers upon a perfectly true arbor or mandrel, and hand reaming both boxes at the same time. The previous diameters should have been made very close to the finished dimensions so as to leave as little as possible to ream by hand. Really the cutting edges of the reamer should barely *scrape* out a very trifle of the metal. In fact, it should be rather a scraping than a reaming job,

but it will generally be found in practice that the reamer will scrape a little harder in one place than in another, showing the practical necessity for its use.

In the drawings illustrating the different forms of bearings and spindles the devices by which the journals are lubricated have been omitted so as not to confuse the question. The matter of lubrication is, however, an important one, and will next claim our attention.

In many cases the spindle bearings are lubricated by means of a simple oil hole closed by a plug of brass. In others a short vertical tube is inserted and covered by a cap which entirely encloses it. In still others the "plain brass oil cup" is used, that is, a simple receptacle, usually urn-shaped, whose top is closed by a cover screwing into it. Again, various patented devices are employed, ranging all the way through "good, bad, and indifferent," whose object is to furnish easy access to the oil tube and to provide, in many cases, for the automatic closing of the oil tube or reservoir for the purpose of excluding dirt.

An improvement upon the plain brass oil cup is shown in Fig. 80. This improvement consists in the introduction of a vertical tube A, whose lower end opens into the hole leading to the journal bearing. This tube is fitted with a wick B, whose lower end rests upon the journal C, and whose upper end is coiled loosely about in the oil chamber. When the oil in the reservoir is above the top of the tube the wick prevents the oil from running down too rapidly. When the oil is below the top of the tube the wick acts as a siphon and thus insures the lubrication of the bearing.

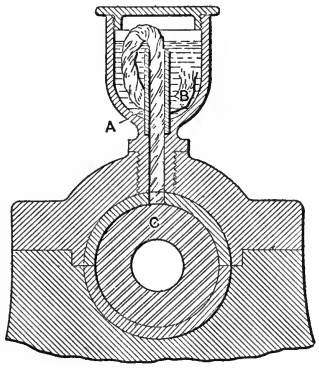


FIG. 80. — Siphon Oil Cup.

The use of a wick is resorted to in the next example, shown in Fig. 81. In this case an oil reservoir is formed in the housing of the head-stock A, and a suitable opening in the form of a slot parallel to the axis of the spindle is cut through the lower box. Into this is fitted a flat wick B, or piece of coarse soft felt whose upper edge

rests against the bottom of the journal C, and whose lower end is immersed in the oil filling the reservoir. Capillary attraction is depended upon for drawing the oil up to the bearing, although with oil at the height shown in the cross section, on the right of Fig. 81, the oil is gradually forced up to the under side of the journal.

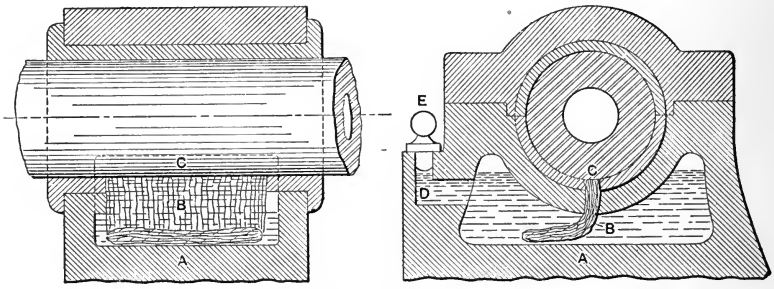


Fig. 81. — Lubrication by Capillary Attraction.

This plan has the advantages of keeping the journal and its lubricant free from dirt; of straining the oil so that any dirt it may contain will not reach the bearing; of providing for a quantity of oil so as to make frequent additions to the supply of oil unnecessary; and of furnishing a handy method of introducing a new supply of oil, by way of the hole D, closed by the stopper E.

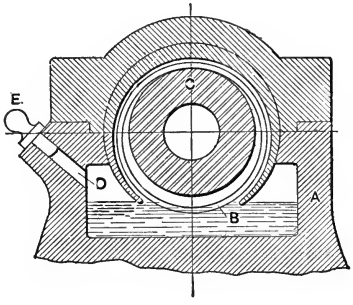


Fig. 82. — Loose Ring Oiler.

In large machines, using a considerable quantity of oil, a drainage tube is provided through which the sediment and dirt may be gotten rid of when necessary. This tube is closed by a stopcock.

This method of lubrication is very largely and successfully used in countershaft boxes, which, from their comparatively inaccessible position are very liable to be neglected in the matter of proper lubrication.

The use of a loose ring for raising oil to the journal bearing is shown in Fig. 82. In this case a loose, flat ring B, of considerable larger inside diameter than the diameter of the journal C, is placed around it and allowed to hang down into the oil in a reservoir

formed in the head-stock A, similar to that shown in Fig. 81. The revolution of the spindle is usually sufficient to keep the ring in motion so as to draw up a sufficient supply of oil to lubricate the bearing. In this case, also, oil may be introduced through the hole D, usually closed by the stopper E. One ring is sufficient for a bearing and is placed in the center of it, the box or box lining material being grooved out for this purpose.

In Fig. 83 is shown a similar device to the above, except that a flat linked chain is used instead of a circular ring. It is obvious that by lengthening the chain it will necessarily dip deeper into the oil than a circular ring possibly could, while the openings in the links of the chain will more readily carry up the oil than will a smooth ring devoid of openings or raised parts. In both the above cases an internal groove is cut in the inside of the journal box to accommodate the ring or chain, and an opening made entirely through at the bottom for the entrance of the oil.

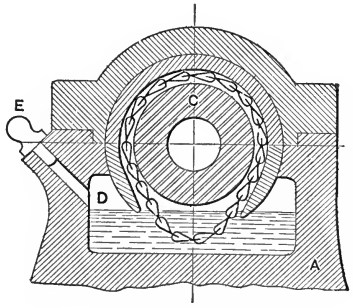


Fig. 83. — The Loose Chain Oiler.

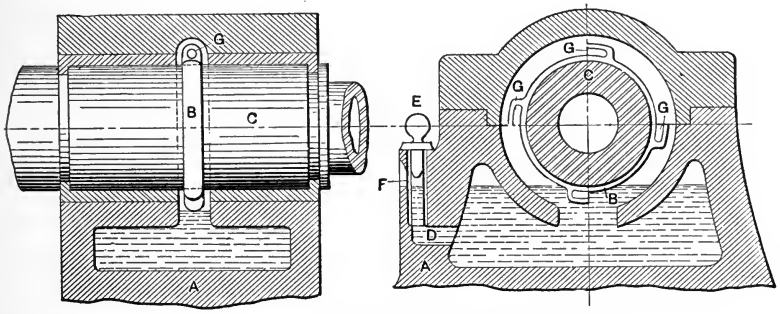


Fig. 84. — The Lodge & Shipley Type of Oiler.

A modification of the ring device is shown in Fig. 84, which illustrates a type of lubrication used in the Lodge & Shipley lathes. It consists of a ring B fixed to the journal and having formed upon it four buckets G, G, G, G, opening in the direction of rotation, whose function is to dip up the oil as they pass through the reservoir and

to pour it over the journal as they successively pass over the highest point of their revolution. Suitable ducts distribute the oil length wise of the bearing and return it to the oil reservoir to be used again and again. Thus a positive provision is made for supplying the journal with oil, and the manufacturers assert that a spindle so fitted up will run for a month without a new supply of oil. The oil reservoirs are said to hold about a pint and the supply is introduced through the oil hole D, which is provided with the glass tube F, closed by the stopper E, and through which the height of the oil in the reservoir may be observed through the opening cut in the metal surrounding the glass tube as shown in the engraving.

The practical utility of such a means of lubrication is at once apparent, as the neglect of workmen to attend to the proper lubrication of lathe spindles, as well as many other parts of the machine where oil is necessary, is one of the most fruitful sources of lathe difficulties that occur. And a spindle that has been allowed to "run dry" and its finely ground and polished surface to become cut and "roughed up" is very difficult to ever get in as good working condition again as before this kind of abuse happened.

The author has known of instances where the designer had provided an oil reservoir which had been filled when the lathe was being tested and which had operated well and lubricated abundantly. The lathe was shipped to a customer, set up and run, and in a few months the parts returned completely destroyed from lack of lubrication, the fact being evident that no oil had ever been placed in the reservoir when the supply first introduced, as above stated, was exhausted. Such neglect of the most ordinary precautions is a good illustration of the very poor shop conditions which still exist in some otherwise well-managed shops.

The gearing in the head-stock of a lathe by which the speed of the spindle is varied is in general terms called the "back gearing," since the purpose of it is to "gear back," that is, to reduce the speed of the spindle.

There are three methods of changing the speed of the spindle, namely: by running the driving-belt on the different steps of the cone; by means of the usual back gearing; and by means of what might be termed a secondary back gear, or as generally termed the

"triple gear." This is by some manufacturers of lathes called the 'double back gear."

In Fig. 85 is shown a diagram of the driving mechanism of a

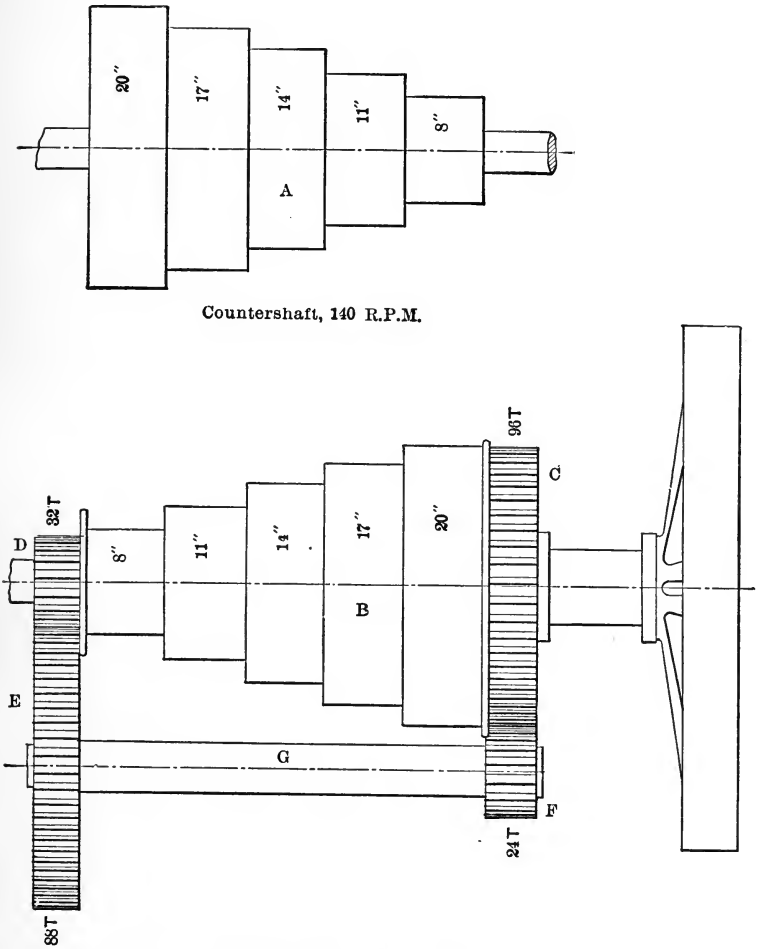


FIG. 85. — Diagram of the Driving Mechanism of a Back Geared Lathe.

back geared engine lathe. At the top of the engraving is shown the countershaft cone A, as this performs an important part in the changing of speeds. The spindle cone B runs loose upon the lathe spindle and is fixed to it at will by a lock bolt passing through the face gear C, which is permanently keyed to the spindle. Upon the

small end of the cone is fixed the cone pinion D, which meshes into the back gear E, which is fixed at one end of the back gear quill, or sleeve G, which carries at its opposite end the quill pinion F. This quill runs freely upon a shaft called the back gear shaft, which is provided at each end with eccentric bearings, and at one end a lever for operating them, by means of which the back gear quill G, with the back gear E and quill pinion F, may be thrown out of engagement with the cone pinion D and the face gear C.

The operation of the device is as follows: the cone B, rotating the cone pinion D at a certain speed, and the back gear E being engaged with it, will rotate the latter at a speed proportional to the number of teeth in the two gears. In this case the cone pinion D having 32 teeth, and the back gear E having 88 teeth, the ratio of their respective revolutions will be as $2\frac{3}{4}$ to 1; therefore, if the cone were running at 275 r.p.m.(revolutions per minute), the back-gear quill would run at 100. This speed is still further reduced by the quill pinion F and the face gear C. These two have respectively 24 and 96 teeth and consequently a ratio of 4 to 1, so that the spindle speed, by the introduction of the back gears and the withdrawal of the lock bolt attaching the cone B and the face gear C to each other, will be reduced to 25 revolutions.

Therefore, if we divide the revolutions per minute of the spindle cone by the ratio of the cone pinion with the back gear multiplied by the ratio of the quill pinion with the face gear, we obtain the spindle speed. Or, in detail, in this case, $88 \div 32 = 2.75$, and $96 \div 24 = 4$, and $2.75 \times 4 = 11$, which is the combined ratio or the normal back gear ratio. In short, the cone speed divided by the back gear ratio will give the spindle speed, thus: $275 \div 11 = 25$.

The various speeds given to the spindle cone by belt changes depend, of course, upon the porportions of the diameters of the various steps of the cone. When there are five steps on the cone, the central step on each cone is usually of the same diameter, and as the two cones are generally cast from the same pattern, so far as the outer shell is concerned, it is simply a question of reversing one so that the belt shall be on the largest step of one and the smallest end of the other, or the intermediate step above or below the central step.

In the diagram shown the steps are respectively 20, 17, 14, 11,

and 8 inches in diameter, and the ratios as follows, viz.: 20 to 8 = 2.5; 17 to 11 = 1.545. These ratios multiplied or divided (according as to whether the step on the countershaft cone is larger or smaller than the one used on the spindle cone) by the revolutions

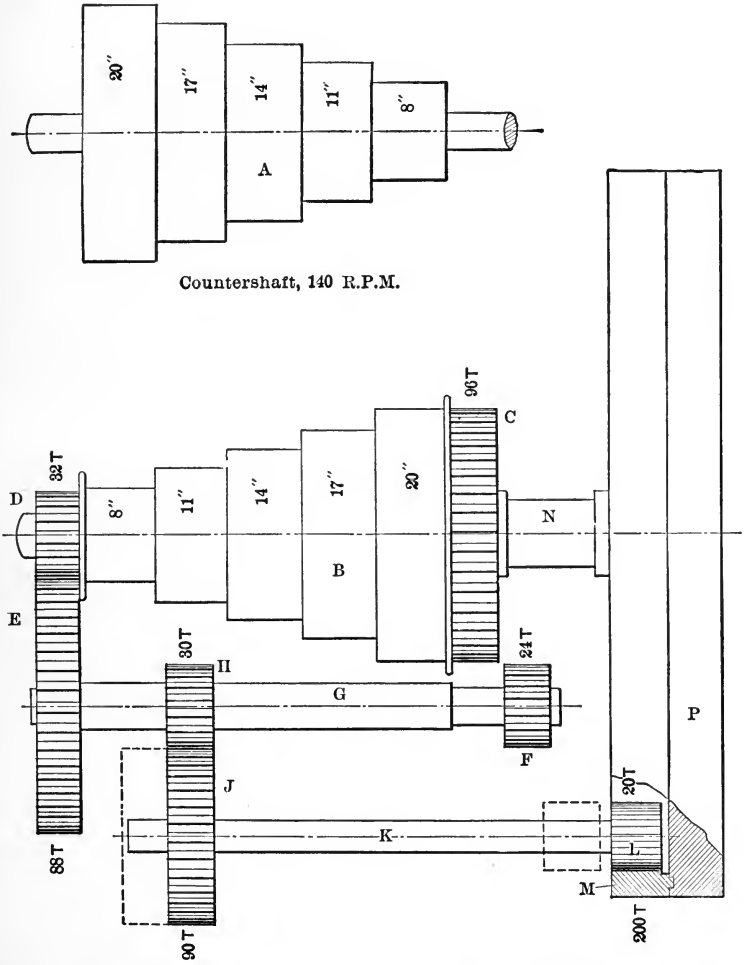


FIG. 86. — Diagram of the Driving Mechanism of a Triple Geared Lathe.

per minute of the countershaft will give the various cone speeds.

Figure 86 is a diagram of the driving mechanism of a triple geared lathe. So far as the countershaft cone, spindle cone, and the back gearing are concerned it is identical with the mechanism

shown in Fig. 85, except that the quill pinion E is so constructed as to slide out of engagement with the face gear, and also that there is a third gear on the back gear quill G, namely the pinion H, which engages the gear J fixed to the triple gear shaft K, which also carries the internal gear pinion L, which in turn engages the internal gear M fixed to the back of the face-plate P, which is attached to the front end or nose of the lathe spindle N.

The triple gear shaft K is adapted to slide endwise in its bearings, and to be retained in either position so as to bring the gear J and pinion L out of engagement with the pinion H and internal gear M when the triple gear is not in use. This position is represented in the engraving by dotted lines.

As the pinion H has 30 teeth and the triple gear J has 90 teeth, the ratio existing between them is 3. And as the pinion L has 20 teeth and the internal gear has 200, their ratio is 10. Therefore, these two ratios multiplied together is 30, which multiplied by the ratio of 2.75, existing between the cone pinion D and the back gear E, produces 82.5, which is the triple gear ratio. It will be noticed that in this calculation the face gear C and quill pinion F are not taken into account, as they are not engaged when the triple gear is in operation.

The following summary of back gear and triple gear, as well as cone conditions, is given for convenient reference:

Cone diameters, 8, 11, 14, 17, and 20 inches.

Countershaft speed, 140 revolutions per minute.

Cone pinion, 32 teeth; back gear, 88 teeth; ratio, 2.75.

Quill pinion, 24 teeth; face gear, 96 teeth; ratio, 4.

Combined ratio, or back gear ratio, 11.

Triple gear pinion, 30 teeth; triple gear, 90 teeth; ratio, 3.

Internal gear pinion, 20 teeth; internal gear, 200 teeth; ratio, 10.

Combined ratio of the triple gearing alone, 30.

Triple gear ratio, including first back gear ratio, and as is usually given, 82.5.

The spindle speeds, with the countershaft running at 140 r.p.m., are given in the following table:

Cone speeds Back Gears and Triple Gears not in use.	Back Gear speeds; Triple Gears not in use.	Triple Gear speeds, including first Back Gear.
56.00	5.09	.690
97.08	8.82	1.175
140.00	12.72	1.696
216.30	19.63	2.621
350.00	31.81	4.240

To graphically illustrate the spindle speeds the diagram in Fig. 87 is given. The principal curve beginning at the bottom of the diagram shows the five cone speeds and the five back gear speeds, while the diagram at the top on a much larger scale gives the five triple gear speeds. From this diagram a good idea of the proportions and the regular progression of speeds may be obtained. While the progression of speeds shown are those proper under the circumstances, it will be found that there are many lathes in the market in which they are not realized, often, doubtless, owing to careless designing. In making this statement it is not meant that the slowest and the fastest obtainable speeds are not proper. It does not mean that the high speeds are not fast enough, since we can readily get a faster speed by speeding up the countershaft. In the same way we may obtain a slower range of speeds by reducing the speed of the countershaft.

But what is meant is that as between the three series of speeds known as cone speeds (or open belt speeds), back gear speeds, and triple gear speeds, there will be too much of a break between these divisions or groups, or there will be an overlapping of speeds so that one or two speeds of one group are very nearly duplicated in the next higher or lower. In this way a triple geared lathe of nominally *fifteen* speeds will give but *thirteen* practically *different* speeds. In the example given in Fig. 87 it will be noticed that the speeds rise in a very regular progression, the numbers up the sides of the diagram giving the speeds and those beneath giving the serial number of the fifteen speeds from slowest to fastest.

To illustrate some of the common faults in the designing of back gears, attention is directed to the four examples shown in Figs. 88, 89, 90, and 91.

In Fig. 88, there is too much of an increase of speed between the

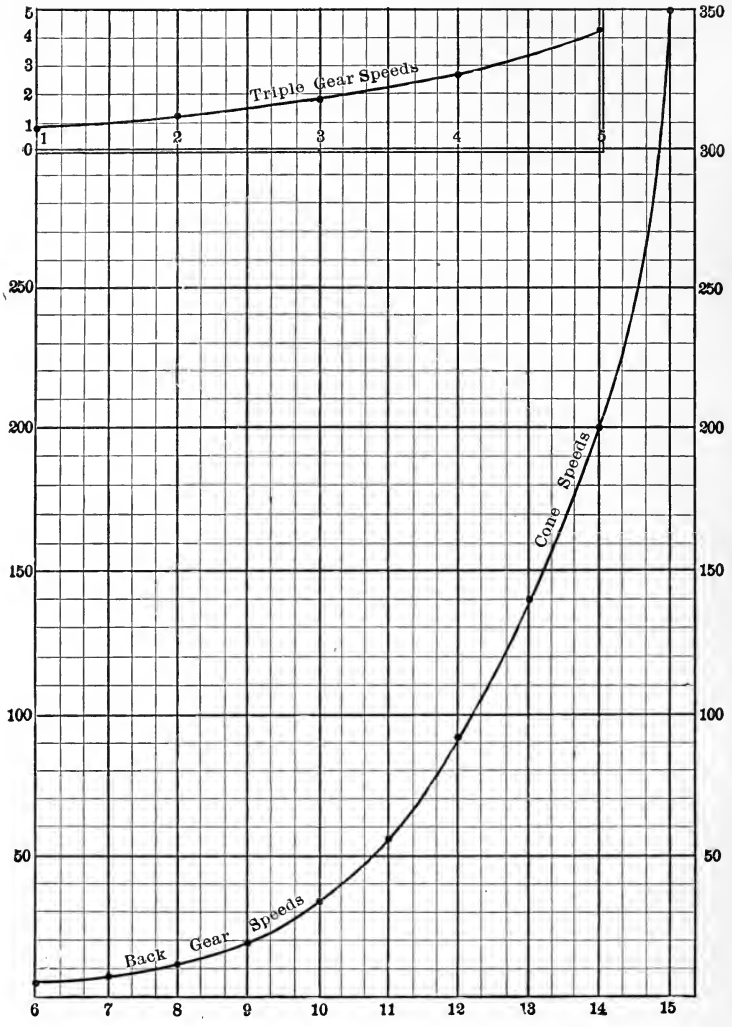


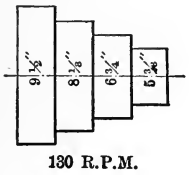
FIG. 87. — Speed Curves of a Triple Geared Lathe.

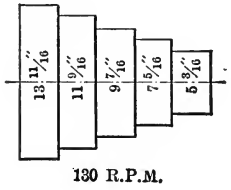
fastest speed of the back gear and the slowest of the cone speed. This amounts to a difference of 47 revolutions, as the former is 48.9, and the latter 96. The entire range of speeds is:

Cone Speeds	Back Gear Speeds
395	48.9
234	29.
149	18.4
96	11.9

The countershaft runs 130 revolutions per minute. The back gear ratio is 8.08 to 1.

In this lathe a four-step cone is used, therefore giving only eight speeds. The lathe is a small one, the swing being 14 inches and intended for light work and a comparatively fast range of





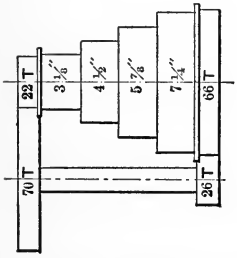


FIG. 88. — Back Geared Lathe, 8 speeds.

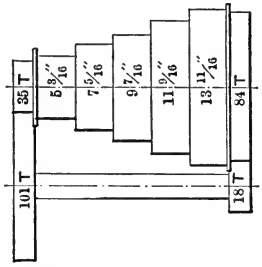


FIG. 89. — Back Geared Lathe, 10 speeds.

speeds. It will be noticed that the countershaft cone is considerably larger than the spindle cone, which is an unusual condition.

In the next example a lathe having a five-step cone is selected. It is a 19-inch swing lathe and intended for much heavier work and back gears having a much wider face, in fact 50 per cent, while the pitch of the teeth is in about the same proportion.

Figure 89 shows the driving mechanism for this lathe, whose back gear ratio is 13.46 to 1, and whose countershaft speed is 130 revolutions per minute.

In this case the increase of speed between the fastest back gear speed and the slowest cone speed is 23.7, while the next speed below varies only 10 revolutions, which is a palpable fault in the caclulation of the speed progression. The following are the spindle speeds:

Cone Speeds	Back Gear Speeds
343.0	25.50
206.0	15.30
130.0	9.65
82.2	6.10
49.2	3.65

For this size of lathe the highest and lowest speeds are as they should be, but the proper progression is at fault.

Figure 90 is a diagram from a lathe of 17-inch swing and having a five-step cone, a back-gear ratio of 12 to 1, and a countershaft speed of 150 revolutions per minute. The same fault of too great a difference between the fastest back gear speed and the slowest cone speed is observed.

The spindle speeds are as follows:

Cone Speeds	Back Gear Speeds
371.0	30.90
231.0	19.25
150.0	12.50
97.5	8.10
60.6	5.05

The difference above referred to is 29.7, while the next difference below is only 11.35.

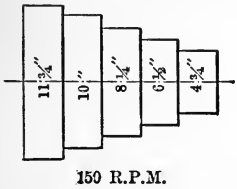
The next example is of a 30-inch swing, triple geared lathe in which the speed calculations show an error only too common among lathes of this type. It will be noticed by reference to the engraving, Fig 91, that the countershaft cone is considerably larger than the spindle cone, which is entirely unnecessary since the same object might have been secured by running the countershaft faster and the parts need not be so heavy or expensive. The questions of proportion and progression of speeds can be easily taken care of when both cones are alike, if the proper calculations are made.

The countershaft speed is 110 revolutions per minute.

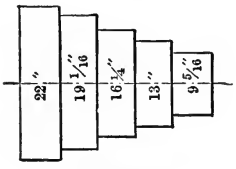
The back gear ratio is 15.23 and the triple gear ratio 57.74 to 1. The spindle speeds are given below:

Cone Speeds	Back Gear Speeds	Triple Gear Speeds
372.0	24.40	6.44
212.0	13.90	3.67
137.0	9.00	2.37
88.7	5.82	1.53
52.5	3.45	.81

By reference to these figures it will be seen that the triple gear speed of 6.44 exceeds both the back gear speeds of 3.45 and 5.82, which renders them comparatively useless, or which makes the two



150 R.P.M.



110 R.P.M.

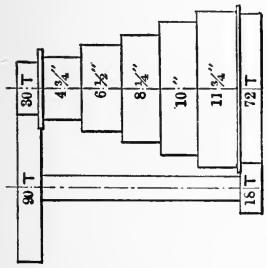


FIG. 90. — Back Geared Lathe, 10 speeds.

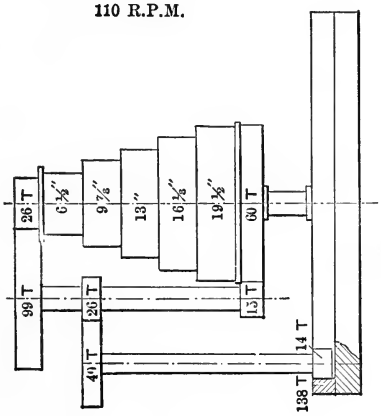


FIG. 91. — Triple Geared Lathe, 15 speeds.

higher speeds given by the triple gears of no effect in practical work. Otherwise, of the five triple gear speeds *two are of no practical use.*

Hence, we have a lathe provided with *fifteen* nominal speeds, which really has but *thirteen.* This point will be more readily appreciated by referring to the speed curve shown in the diagram,

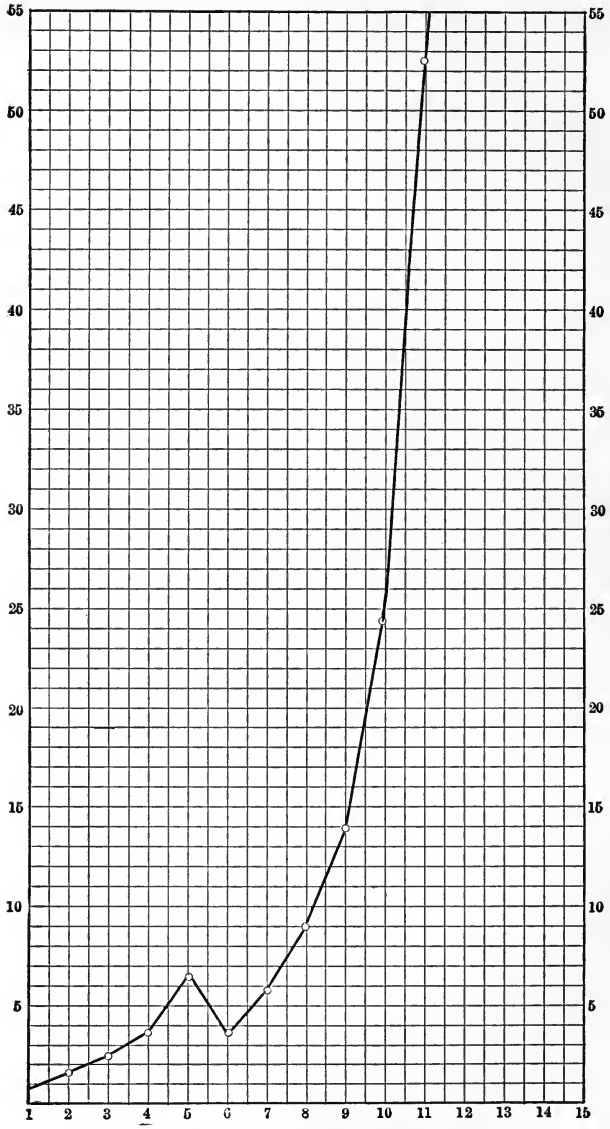


FIG. 92. — Speed Curve of a Triple Geared Lathe Wrongly Designed.

Fig. 92, and the faults of designing more clearly brought out by comparing this diagram with the two curves shown in the diagram given in Fig. 87, being careful to note that the upper curve repre-

senting the triple gear speeds is drawn to a scale ten times larger than the curve for the back gear speeds and the cone speeds. The object of this was to show more clearly the progressive increase of the triple gear speeds, whose continued upward tendency would properly join with those of the back gear if the latter were drawn to the same scale, which the dimensions of the page would not admit.

The figures for these speeds are given on a previous page, to which the reader is referred, and a comparison with the speeds given in the last example is suggested.

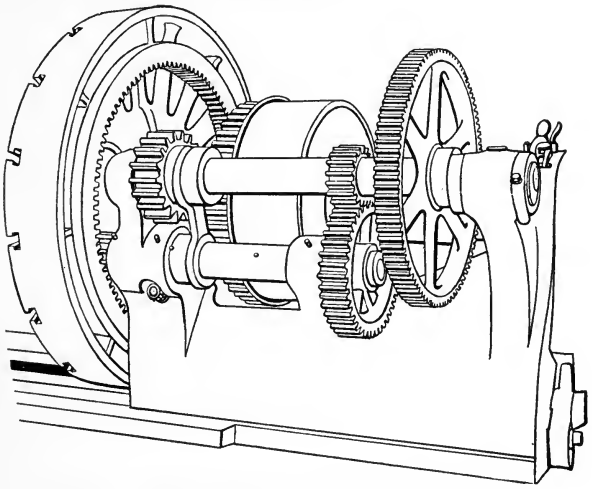


Fig. 93. — Triple Gearing of a Lodge & Shipley Lathe.

In the diagrams of driving mechanisms in Figs. 85, 86, 88, 89, 90, and 91, the countershaft cone is shown above the spindle cone and the back gear and triple gear mechanisms below. This is so arranged for convenience in giving the relative dimensions and proportions of the parts. While it is the usual method to place the back gear device at the back of the lathe head-stock or in the rear of the spindle, it is not at all necessary that it should be so placed, and in fact, on some of the larger lathes, it is placed in front of the main spindle as a matter of convenience.

The essential parts of the triple gear mechanism in connection with the usual back gears are well represented in the rear view of a head-stock shown in Fig. 93, in which the triple gear device is shown engaged and the quill pinion thrown out of engagement with

the face gear. In this case a clutch connection between the back gear shaft and the triple gear shaft serves to handle the pinions on both so as to be moved into and out of engagement at one and the same time, thereby running the lathe as a back geared or a triple geared lathe, by a very simple and convenient change. The design is of a lathe built by Lodge & Shipley.

While it is not the intention of the author to assume to present in this work an exhaustive treatise on lathe design, for the reason that the scope of the plan is not extensive enough to permit it, and for the further reason that it does not seem necessary in view of the objects for which it is written, it does seem thoroughly in keeping with what is proposed, to give such facts as to some of the more important points of design as will serve as cautions to the designer, as interesting lines of thought to the machinist, and as information to the buyer of lathes.

These have been the considerations governing what has been presented in relation to back gearing and triple gearing as well as dimensions of cone steps.

There are several matters intimately connected with this subject which seem to merit still further consideration.

Any one who will take the trouble to examine, as the author frequently has, a lot of lathes in almost any machine shop and to make the most superficial calculations of their speeds, will be surprised at the amount of apparent "*guesswork*" that has entered into their design. The speed curve shown in Fig. 92 is a case in point. Narrow-faced back gears without any calculations, so far as one may see, of the strain which they must bear; small pinions, whose teeth are soon *ground* away on account of the sharp angles of their action; a lack of proper proportion between cone dimensions and back gear dimensions; and many other similar faults.

We have all seen lathes with a 3-inch vertical belt on a 5-inch cone, while the overhead horizontal belt driving the countershaft was 4 inches wide on a 15-inch pulley; when every mechanic knows that a horizontal belt will drive more than a vertical one, aside from the difference in the diameters of the pulleys being all in favor of the larger pulley.

When we consider these questions we cannot avoid the conclusion that there have been many good opportunities wasted and

that the money spent for these machines should have produced much more really practical and useful machines than it has, and that they should have been capable of turning out a much larger output than we find them doing.

In designing a lathe head-stock the triangle formed by the distance from center to center of the inside V's, as a base, and the lathe center the apex, should be an equilateral triangle. Sufficient material must be provided under the largest step of the cone and the face gear to give the requisite strength and rigidity. The large step on the cone should fill the remaining space with the exception of a sufficient clearance for the belt. The large diameter of the cone having been thus fixed the diameters of the other steps are a question of proportion, according to how many steps there are and what is to be the smallest diameter. It is common practice to make the steps of the spindle cone and the countershaft cone identical. This, on a five-step cone, will give a spindle speed (without back gears) equal to the countershaft speed when the belt is on the middle step. The spindle speed will be correspondingly faster or slower according as the belt is on the smaller or larger steps of the spindle cone, and in the same proportion as the cone steps are to each other.

The cone diameters having been fixed *the back gear ratio must be made to correspond.* We cannot have an arbitrary cone proportion and an arbitrary back gear ratio. Only one can be fixed, and the other must be arranged to correspond with it.

A homely proportion, but one that will come out very nearly right in practice, in determining the proper width of face for the cone steps, will be one seventh of the swing of the lathe when no triple gears are used. If triple gears are used it is common practice to make the belt a trifle narrower. The present tendency is towards wider belts and it seems to be a very proper development made necessary by modern shop conditions and the use of high-speed steel tools. It is altogether probable that belts will be made wider rather than narrower in the future.

There is also a tendency to make the differences between cone step diameters less, which gives a larger diameter to the smaller steps, and consequently more power in the driving mechanism of the lathe and avoids the necessity for very tight belts.

Ordinarily, the width of the face gear should not be less than eight tenths of the width of the cone steps, and the width of the back gear not less than six tenths. Of course, the pitch of the teeth should be in proper proportion to the width of the face, and in the larger lathes the pitch of the teeth of the face gear should be one number coarser than that of the back gear.

Usually the face gear has an outside diameter about equal to that of the largest step of the cone, but should not be larger. The outside diameter of the cone pinion should not be much smaller than the smallest cone step. These dimensions thus coming within rather narrow limits, the diameter of the back gears and that of the quill pinion will be governed by the ascertained or the arbitrary back gear ratio.

In order to avoid the interference of a large back gear with the desired form of the head-stock at this point, and to secure a symmetrical contour, the back gear shaft can advantageously be raised above the level of the main spindle. This is permissible to the extent of $1\frac{1}{2}$ inches on a 36-inch swing lathe.

The method of transmitting the power from the spindle to the feeding mechanism, formerly done almost exclusively with a belt on cone pulleys, one of which was upon the head shaft (located below the spindle and driven by it through the medium of gears), and the other on the feed rod. The lead screw was, of course, driven by gears so as to obtain a positive motion. In modern lathes nearly all have gear-driven mechanism for both the rod feed and the screw feed.

The former practice of reversing the feed in the head-stock is now to a large extent abandoned, and this function performed at the apron, and is much more convenient to the operator.

The mechanism for driving the lead screw in thread cutting and for a large range of feeds is now very popular and is accomplished wholly by gears with appropriate levers, shafts, and clutches. Those for driving the feed rod are usually known as "variable-feed devices" and those for thread cutting are known as "rapid change gear devices." It is not unusual to find these combined so that one set of variable-speed gears is adaptable to both functions.

These devices will be considered further on in this work, and representative inventions for these purposes will be given.

CHAPTER VII

LATHE DESIGN: THE TAIL-STOCK, THE CARRIAGE, THE APRON, ETC.

Functions of the tail-stock. Requisites in its construction. The Pratt & Whitney tail-stock. The Reed tail-stock. The Lodge & Shipley tail-stock. The Blaisdell tail-stock. The Hendey-Norton tail-stock. The New Haven tail-stock. The Prentice tail-stock. The Schumacher & Boye tail-stock. The Davis tail-stock. The American Watch Tool tail-stock. The Niles tail-stock for heavy lathes. New Haven tail-stock for heavy lathes. The Schumacher & Boye tail-stock for heavy lathes. The Bridgford tail-stock for heavy lathes. The Le Blond tail-stock. The lever tail-stock. The lathe carriage. Requisites for a good design. Description of a proper form. A New Haven carriage for a 24-inch lathe. The Hendey-Norton carriage. The Blaisdell carriage. The New Haven carriage for a 60-inch lathe. Criticisms of a practical machinist on carriage and compound rest construction. Turning tapers. The taper attachment. Failures of taper attachments. The Reed taper attachment. The Le Blond taper attachment. The Lodge & Shipley taper attachment. The Hamilton taper attachment. The Hendey-Norton taper attachment. The New Haven taper attachment. The Bradford taper attachment.

THE function of the tail-stock is to support the end of the piece of work opposite to the head-stock; to furnish a movable center for various forms of drills, reamers, and similar tools; and to carry one end of boring bars when the work is clamped to the carriage.

For these purposes it must be of sufficient strength and rigidity to withstand the strain to be put upon it; it must have a traveling spindle to carry the tail center; and be capable of being "set over" in a direction at right angles to the center line of the lathe, for the purpose of turning tapers, and in some types of lathes for boring operations.

It is fitted to the two inner V's of the lathe the same as the head-stock, so as to permit the carriage wings to run past it, and must be capable of being securely clamped in any position along

the length of the bed. The spindle must be adapted to be handled by a hand wheel upon the traverse screw in small and medium sized lathes, and in large lathes located conveniently in front and connected with the screw by suitable shafts and gearing. The spindle should be adapted to be clamped at its front end in an efficient manner so as to hold it firmly and at the same time not to force it out of correct alignment with the head-stock spindle.

The tail-stock should have a long bearing upon the V's, which should be at least two thirds of the swing of the lathe. The bolts for clamping it down should be considerably nearer the front than the rear end so as to counteract the lifting tendency due to pressure against the center. In lathes of 12 to 30-inch swing two bolts will be sufficient to rigidly secure it to the bed. In larger lathes, four bolts should be used.

For the purpose of setting over for turning tapers the tail-stock is composed of a low base and the movable part of the tail-stock proper, the transverse adjustments being made with a cross screw furnished with a square head. The two parts are held together by the holding-down bolts which secure the tail-stock to the bed. In larger lathes, say from 30-inch swing up, the division between the two parts is near the top, which should be secured by an additional set of four bolts so that the spindle may be set over without releasing the holding-down bolts which secure it to the bed. Thus, if a heavy piece of work is supported upon centers the tail spindle may be set over for turning tapers without removing the work from the centers.

In lathes of 24-inch swing and over there should be a rack and pinion device for moving the tail-stock to any desired position on the bed. In lathes of 36-inch swing and over this device should be back-geared so as to give sufficient power to easily move the heavy mass.

This back gearing should begin with a ratio of two to one, and increase as the lathe is larger and the tail-stock is heavier, so that one man may conveniently do the work.

Engravings of tail-stocks, as designed by prominent builders, are introduced to illustrate these conditions and the manner in which they have been met.

The Pratt & Whitney tail-stock is shown in Fig. 94. Its par-

ticular feature is the overhang at the front end for giving extra support to the spindle. The spindle is larger than usual, which gives better support to the center and is very useful when using it to support the rear end of a drill or reamer when long holes are to be drilled or reamed. It is secured to the bed by an eccentric and lever device which is quick and convenient.

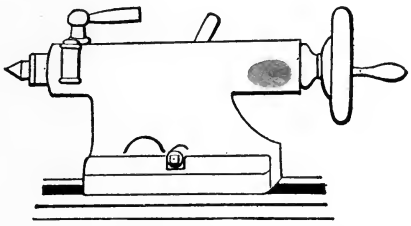


Fig. 94. — 14-inch Lathe Tail-Stock, built by the Pratt & Whitney Company.

Figure 95 shows a front view of a Reed tail-stock for a 27-inch swing lathe. It will be noticed that the holding-down bolts are in line with the bed and both at the front of the upright supporting the spindle sleeve. They are so placed to permit the upright to be cut away in front so as to permit the compound rest to swing around to a position much nearer parallel with the line of the bed than with the ordinary form. A rear view is shown in Fig. 96, which is of the same tail-stock except that a three-bolt crank replaces the hand wheel. The form of the casting is well shown as seen from the rear. This form is called the "off-set tail-stock."

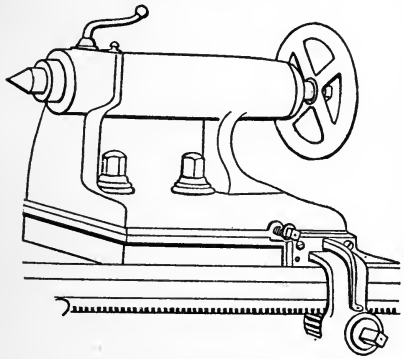


Fig. 95. — Front View of 27-inch Lathe Tail-Stock, built by the F. E. Reed Company.

Figure 97 is an excellent view of the Lodge & Shipley type of tail-stock for small lathes, and shows their device for clamping the spindle, and the mechanism of the tail-spindle screw. The contour of the casting might be improved so as to appear more

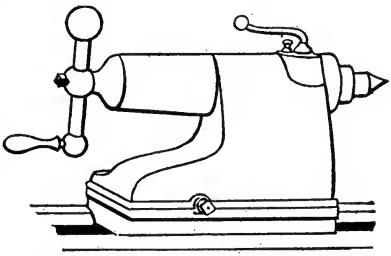


Fig. 96. — Rear View of the Reed Tail-Stock.

clean and symmetrical, without detracting from its solid and substantial appearance.

Figure 98 is the tail-stock used on 20-inch swing lathes built by P. Blaisdell & Company. The only noticeable feature is the unusual diameter of the tail-spindle sleeve in proportion to its sup-

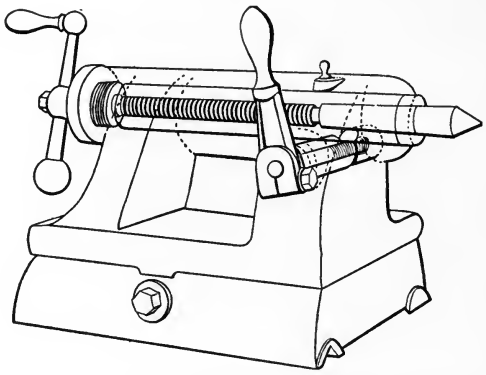


FIG. 97. — Tail-Stock of the Lodge & Shipley Lathes.

porting parts. The cap at the rear end is of such form and dimensions as to increase this top-heavy appearance.

The Hendey-Norton tail-stock for 20-inch swing lathes is shown in Fig. 99. It is a clean, symmetrical, and well-designed piece of work and a considerable improvement on the one just before it. It is secured to the bed by a lever and eccentric arrangement similar to that shown in Fig. 94.

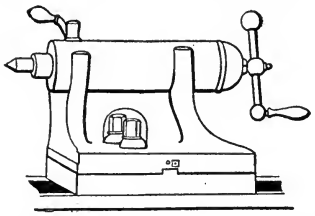


FIG. 98. — 20-inch Lathe Tail-Stock, built by P. Blaisdell & Company.

Figure 100 shows the New Haven Manufacturing Company's tail-stock for 24-inch swing lathes. A finished sleeve screwed into the rear of the main casting furnishes the support for the tail-spindle screw and adds to the otherwise clean outline and substantial appearance of the base. It is very rigid and substantial.

Figure 101 shows the Prentice Bros. Company's tail-stock, which they claim as their invention so far as American lathes are concerned. Other than this fact there is nothing particularly notice-

able in its design except that there are two ribs and grooves, one to each bolt for preventing the undue strain on the holding-down bolts. These bolts are well spread apart, which is a good feature in some respects if not in others.

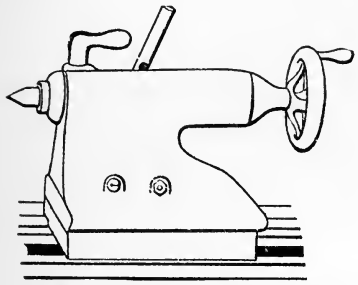


FIG. 99. — 20-inch Lathe Tail-Stock, built by the Hendey Machine Company.

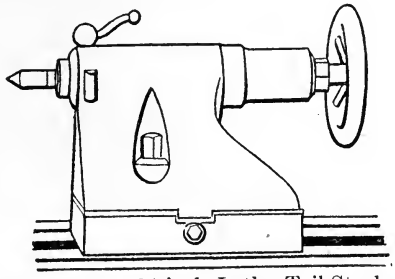


FIG. 100. — 24-inch Lathe Tail-Stock, built by the New Haven Manufacturing Company.

The Schumacher & Boye tail-stock shown in Fig. 102 is a good general design and resembles that of the Hendey-Norton manufacture. Aside from the very prominent cap at the rear end it is a very creditable appearing device, and considerably better than some of those short and square forms which appear "all in a bunch," as it were.

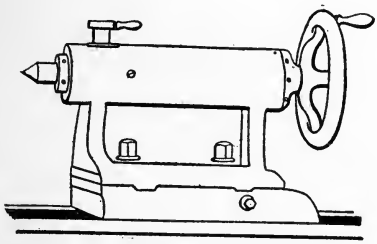


FIG. 101. — 22-inch Lathe Tail-Stock, built by the Prentice Bros. Company.

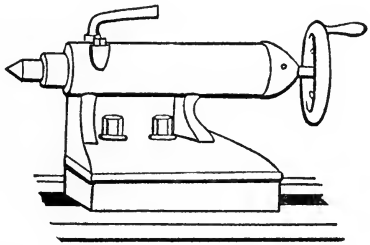


FIG. 102. — 18-inch Lathe Tail-Stock, built by Schumacher & Boye.

Figure 103 shows the W. P. Davis machine Company's production, which is of fairly good proportions and has ample strength. While it is for only a 28-inch swing lathe, it is provided with a rack and pinion device for moving it along the bed.

The Bench lathe tail-stock is well shown in Fig. 104, the engraving being of the type made by the American Watch Tool Company.

It is chiefly noticeable for the very long spindle which it carries. This type of tail-stock does not usually have the set-over feature. It is clamped to the bed by a lever-nut turning horizontally.

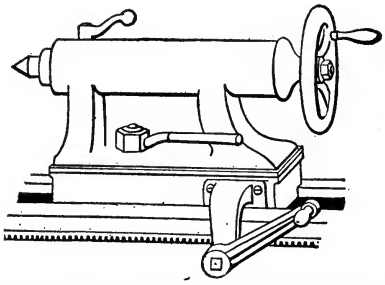


Fig. 103. — Tail-Stock built by the W. P. Davis Machine Company.

Of the heavier tail-stocks, for large lathes, the Niles type is shown in Fig. 105. This is divided near the bottom, as in the usual design for small lathes, and secured to the bed by four bolts. It has a rack and pinion device for moving it along the bed, and otherwise is of ordinary design and construction, without special features to which attention need be called.

The tail-stock shown in Fig. 106 is of the same general form as that shown in Fig. 100, by the same concern, the New Haven Manufacturing Company. This is for a 60-inch swing lathe, and is a very massive and rigid tail center support. It has proportionately a long bearing on the bed, to which it is secured by four heavy bolts.

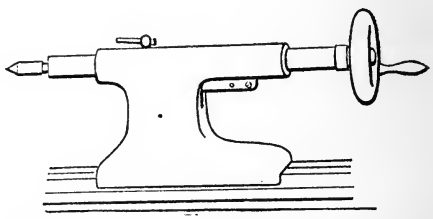


Fig. 104. — Bench Lathe Tail-Stock, built by American Watch-Tool Company.

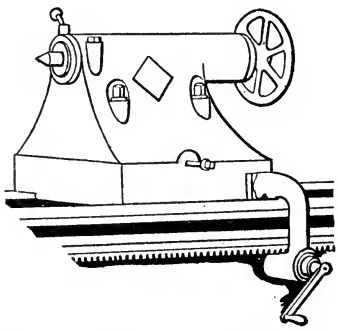


Fig. 105.—42-inch Lathe Tail-Stock, built by the Niles Company.

It is divided near the top and the upper portion secured to the lower by four other bolts of ample diameter, by which means heavy work held on the centers need not be removed or blocked up when setting over for turning tapers. As the spindle sleeve is very long and the tail spindle large and heavy, a spur gear is keyed to the spindle screw and engages a spur pinion on a shaft in front. Upon the front end of this shaft is a miter

gear which engages with a similar one fixed to a short transverse shaft upon whose front end is a large hand wheel by which the tail spindle is easily and conveniently operated. The ratio of this gearing is 3 to 1. The tail-stock, which is very heavy and massive, is moved along the bed by a rack and pinion device, also back-geared at a ratio of 3 to 1, by which one man may easily move the tail-stock from one point to another, although it weighs nearly a ton.

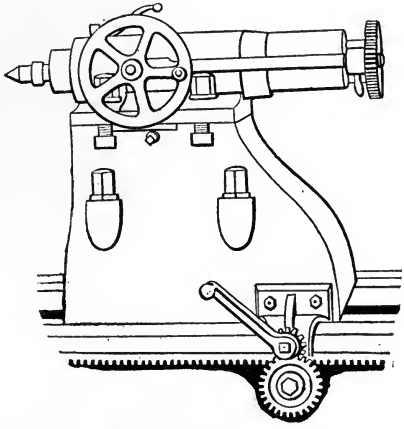


FIG. 106. — 60-inch Lathe Tail-Stock, built by the New Haven Manufacturing Company.

The establishment of Schumacher & Boye make a somewhat similar tail-stock for their 48-inch swing lathe. It is shown in Fig. 107. It is provided with the same features as the one just considered, but has the hand wheel set at an angle, with the intention, probably, of rendering its position more convenient to the operator. It is not as massive or rigid as the last one shown, but doubtless serves a good purpose.

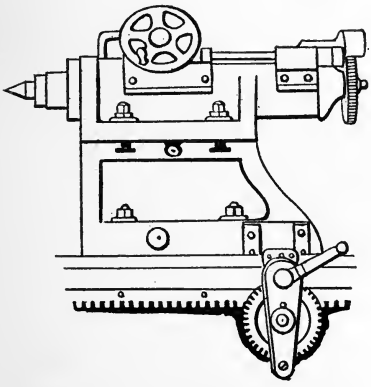


FIG. 107. — 48-inch Lathe, built by Schumacher & Boye.

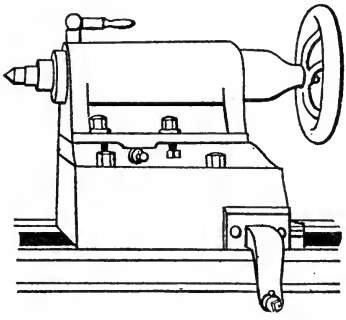


FIG. 108. — 42-inch Lathe Tail-Stock, built by Bridgford Machine Tool Works.

Figure 108 shows a design of tail-stock made by the Bridgford

Machine Tool Works for their 42-inch swing lathe. It is of peculiar design and the base has the appearance of having been "built up in the sand," from the pattern designed for a lathe of much less swing. It is not a handsome design by any means, although it probably serves the purpose of supporting the tail spindle. It has a rack and pinion device for moving it along the bed. Its length on the bed is not as great as it should be, nor do the holding-down bolts seem large enough for a lathe of 42 inches swing. It has four bolts for holding down the base and a second set for securing the top part carrying the tail-spindle sleeve.

At A, Fig. 109 is one of Le Blond's favorite designs and which are used upon most of the lathes built by this concern. Its peculiar feature is the form of the tail-spindle sleeve with its very much enlarged front end. While it has a strange and unusual appearance, its form is based on sound principles of construction and is no doubt practical in giving more stability and rigidity to the tail center, which is a very desirable feature.

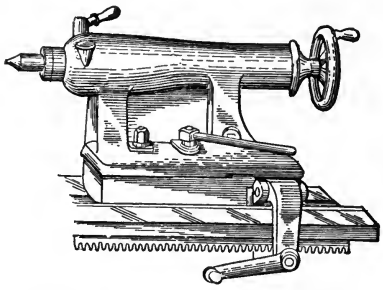


FIG. 109. — The Le Blond Form of Tail-Stock.

From the foregoing illustrations and descriptions the various features of tail-stocks, made by the different manufacturers, may be quite readily studied and their good and bad points duly considered, either for the purposes of designing a new lathe or for purchasing one suitable for the special line and class of work to be performed.

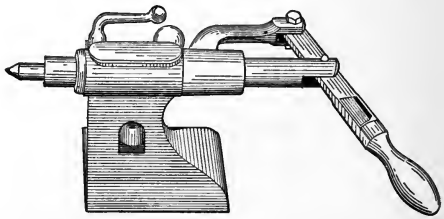


FIG. 110. — Lever Tail-Stock for Hand Lathes, built by the F. R. Reed Company.

At B, Fig. 110, is the ordinary form of what is known as the "lever tail-stock," which is mostly used upon hand lathes. As its name implies, the tail spindle is moved lengthwise by a lever rather than a screw and hand wheel.

This form offers facilities not possessed by the other form, or possessed in a less convenient form. In this spindle may be carried drills, reamers, etc., for use on light work held in a chuck. It may carry a small face-plate against which work may be held and drilled or reamed by a drill or reamer held in a chuck. It may carry an inside boring tool, and if made with a "set-over" device, such as is used on the tail-stock of an engine lathe, its usefulness is still further extended, particularly when working brass or other soft metals or materials. This design is by the F. E. Reed Company.

In addition to all the requirements thus far enumerated, which a lathe must possess in order to do good and heavy work, it must have a substantial carriage and compound rest or other tool-holding mechanism.

The carriage must support the compound rest on top and the apron hanging down at the front. Through the latter it must receive its driving mechanism as the lathe is now constituted. If we were to design a lathe with a view only to the theoretical requirements, we should, of course, put the device for moving it along the bed "on the cut," as near the cutting-tool as possible, and therefore the lead screw and feed-rod would be inside the bed and at some point between the front V and the central line. But we all know the practical objections to this and recognize it in lathe design.

There are a few points in the design of a good lathe carriage that it will be well to call attention to, since they are those that are frequently lost sight of, if we consider many of the present-day designs, and that the buyer of lathes as well as the machinist will do well to give attention to.

Figure 111 shows the design of an ordinary engine lathe carriage intended to be rigid and substantial. It has a wide center part, which is properly supported by the two ribs, thick and deep in the center. The only opening through it is one of moderate dimensions for permitting the chips to pass through.

The entire top is on one level so that large work to be bored may be bolted down upon it when the compound rest is removed for that purpose. Some lathe carriages have the dovetail, upon which the compound rest shoe runs, raised above the general level of the carriage. When work is to be bored it must rest upon

this in the center while the sides are supported upon parallels with attendant inconvenience in bolting down rigidly. In this design there are four T-slots in front and two in the rear for the accommodation of bolts, while others may be passed through the chip opening in the center if necessary.

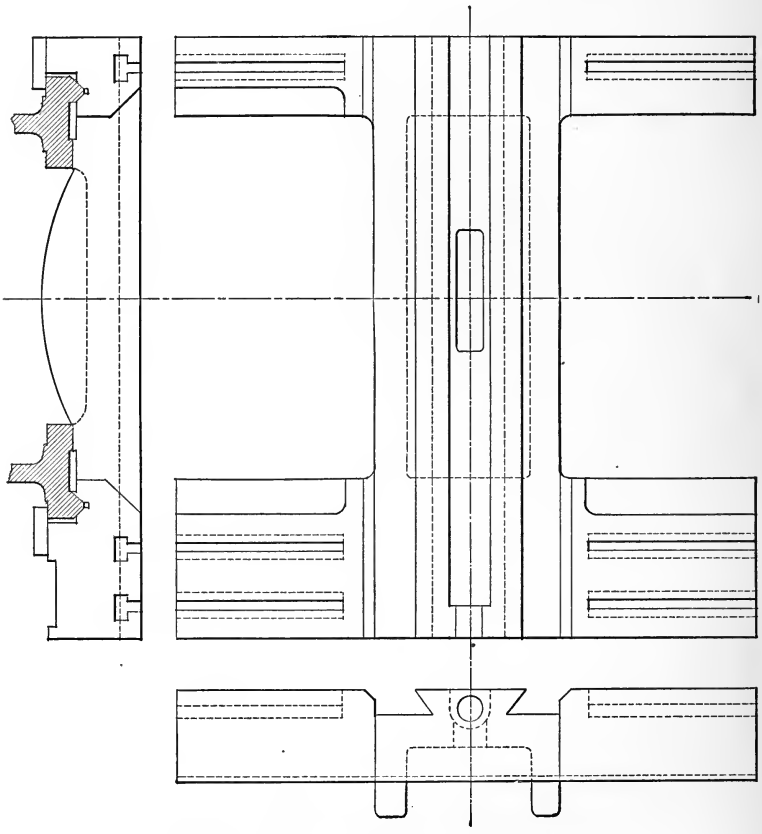


Fig. 111. — Engine Lathe Carriage Design.

The front wings of the carriage are broad, for the purpose of properly accommodating a full swing rest, an additional tool-post or other tool-holding device. The T-slots in the rear may serve a like purpose, or in conjunction with those in front serve for holding down any special attachment necessary.

The design of the bed is such as to furnish additional bearing

surfaces for the carriage inside of the V's, the inner V's being replaced by flat surfaces, thus permitting the swing to be increased and the carriage very materially strengthened.

The carriage is gibbed to the bed on the outside of the V's, both back and front, thus spreading the gibbed surfaces as far apart as possible.

Following this will come in due order illustrations of a few of the carriages and compound rests built by some of the prominent manufacturers.

Figure 112 shows the carriage, apron front, and compound rest of a New Haven 24-inch swing lathe. The T-slots in the rear wings of the carriage are as shown in Fig. 111, but those in the front wing are at right angles. In some cases this is preferable, but if the carriage is to be used much for boring purposes the slots will be found most desirable if all in one direction. The top of the carriage is level, with no obstructions when the compound rest is removed.

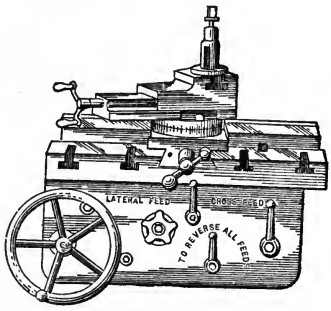


FIG. 112. — The New Haven Carriage, Apron, and Compound Rest for Lathes up to 32-inch swing.

The apron front is clear of gears and other similar obstructions, and the uses of the levers are indicated by plain lettering on the front of the apron. As the levers are set in the engravings all feeds are "out." The "star nut" closes the friction of the driving bevel gear, and the feed is "on" to the right or left according as the lever, marked "to reverse all feeds" is thrown to the right or left. To operate either the lateral or cross feeds the upper lever is thrown to the left for "lateral feeds," and to the right for "cross-feed." The lever at the extreme right closes the "split nut" on the lead screw, provided the feeds are not engaged. That is, if the levers are as shown the lead screw nut may be closed. But if the lever "to reverse all feeds" is moved to the right or left, the split nut is locked "open" and cannot be closed.

The feed rod carries two bevel pinions arranged in a sliding frame, operated by the lower lever, the two bevel pinions being

adapted to be engaged on either side of the driving bevel gear which transmits the motion through the medium of a conical friction clutch operated by the "star nut" in front of the apron.

Further than these bevel gear connections there are no gears but those leading up to the cross-feed screw and back to the rack pinion and hand-wheel shaft. No worm or worm-gear is used. Consequently the parts are large, strong, and durable.

The compound rest, as will be seen, is of ample proportions, has a graduated base, a convenient removable double crank, and a tool-post provided with a concave ring and washer adjustments for the tool.

The entire mechanism has proven very satisfactory in practical use.

The Hendey-Norton carriage, apron, and compound rest is shown in Fig. 113. It is not as conveniently arranged in front of the apron as in the last example. The carriage has the projecting dovetail in the center instead of the flat surface, and only two T-slots are shown in the front wing of the carriage.

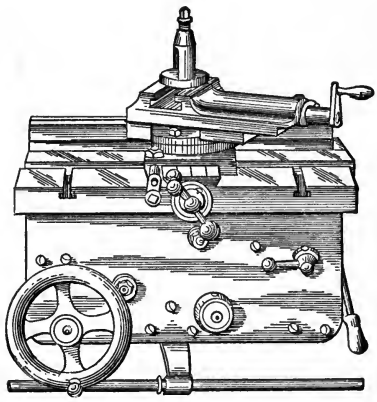


FIG. 113. — The Hendey-Norton Carriage, Apron, and Compound Rest.

The compound rest is a nice piece of designing and construction. It has a graduated base and a tool-post of unusual strength and rigidity. The single crank on the compound rest screw is not as convenient for many uses as a double crank.

The cross-feed screw carries a very convenient graduated disc, which ought to be provided for all lathes up to 32-inch swing, and is useful in many ways for even larger lathes where fine work is to be done.

Figure 114 shows the carriage, apron, and compound rest of the Blaisdell lathes. While the construction is strong and substantial, it cannot be said that it is very symmetrical or with any attempt at fine lines. The arrangement of the apron front is

hardly modern, although there is no gearing or unnecessary part exposed.

A single T-slot is located in the front carriage wing. The carriage and apron are the same length, which usually indicates that the bearing of the carriage on the bed is not as long as it might be to good advantage. The cross-slide dovetail projects above the general level of the carriage so that it would be in the way for boring operations.

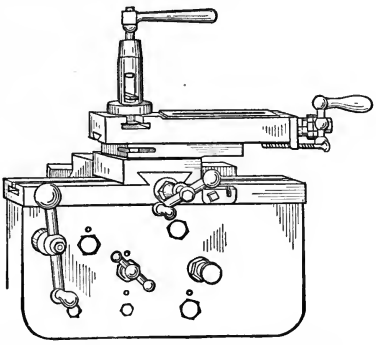


FIG. 114. — The Blaisdell Carriage, Apron, and Compound Rest.

Figure 115 shows the front of the carriage and the compound rest of a 60-inch swing, New Haven lathe. The top of the carriage is level and has three T-slots on each side, in the front wings. The carriage is very massive, weighing about 1,600 pounds, and the compound rest considerably over half that amount.

The compound rest has a large, circular, graduated base and supports a very broad and heavy tool block. The tool is held by

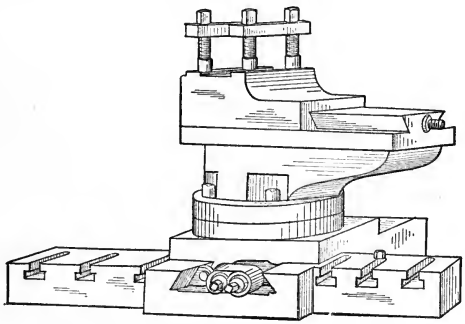


FIG. 115. — The New Haven Carriage and Compound Rest for Large Lathes.

heavy steel clamping bars held up under the nuts by large spiral springs so that the tool may be readily introduced. These clamping bars project, at the ends, beyond the holding-down studs so that the tool may be placed outside the studs when the nature of the work requires that position.

The entire device is very strong and rigid and capable of withstanding very heavy cuts. There is a power cross and angular feed in addition to the facilities for hand feeding in all directions.

Further illustrations and comments upon the various features of this class on the lathes built by different makers will be found in later chapters of this work, describing the entire lathes, and to which the reader is referred for further information.

A practical machinist has recently made the following criticisms upon one of the popular lathes which shows the standpoint from which the practical men look at some of the lathe features. It is so eminently commendable as to be well worth preserving.

First. — The tool block will not travel beyond the line of centers to permit holding small boring tools directly in the tool-post by means of any of the holders so often described which use V-block clamps and make a handy tool-holder. This distance is short $\frac{9}{64}$ inch. It is often convenient to get beyond the centers, and to my mind, at least, an inch is a great advantage.

Second. — The stock in the tool-post is so short that it is impossible to use packing on top of the tool when doing delicate work with small tools made of wire or small straight bars, and without such packing the value of this style of tool is lost. The top of a $\frac{1}{2}$ x 1-inch tool can be raised but $\frac{3}{16}$ inch above the centers.

Third. — The tool-post screw is so short that the wrench runs into the clamp handle of the tail spindle, and either the rest must be removed or the wrench taken off and the screw turned with the fingers when more than a bare loosening is required. The addition of $\frac{3}{4}$ inch to the length would avoid this difficulty and also permit the wrench to swing clear over the small face-plate.

Fourth. — The key in the lead screw for change-gears is of the Woodruff style, and falls out every time a gear is taken off. Of course this gear does not require changing often; if it did this nuisance would be unbearable and call for a properly fitted and fastened key, but as it is, the gear is changed so seldom that one forgets this key, and so it drops and must be hunted for nearly every time a gear is changed.

Fifth. — The centers are of No. 2 Morse taper, but the holes are reamed just enough larger or deeper so that no tool of that taper as fitted to the regular Morse socket can be held without a sleeve

of metal or paper. This may have its advantages in preventing the too common use of such tools in the center holes, but is sometimes a great aggravation in a tool-room lathe, where every convenience would be duly appreciated.

Sixth. — The face-plate fit, so far as the screw thread is concerned, is all right, but the part chambered out next the shoulder is $\frac{1}{16}$ inch larger than the top of thread, which makes it quite difficult to start the thread true when putting on plates or chuck, with the results that the thread often jams in starting, especially with a heavy chuck.

The turning of tapers is often accomplished by "setting over" the tail-stock to the front or rear as may be desired, so as to be out of line with the head-stock center and thereby inclining the axis of the piece to be turned with the axis of the lathe. While this is a convenient and efficient manner when the taper is one of moderate inclination, it can only be done within comparatively narrow limits.

We must therefore resort to some other method when the taper is greater than will be possible to do by setting over the tail-stock and throwing the centers so much out of line with each other as to wear them out of shape as well as to distort the form of the center-reamed holes in the ends of the piece of work.

The taper attachment was devised to meet this condition and consists essentially of fixing to the bed a bar capable of being adjusted horizontally to any desired angle, and upon which is fitted a sliding block, moving with the lathe carriage, and so attached to the tool-supporting mechanism as to cause the cutting-tool to follow in a line parallel to the inclined bar as the carriage is moved to and fro on the bed. This is accomplished by different devices by the various lathe builders, whose efforts are usually directed to three principal objects: first, to so construct the taper attachment that it may be attached to any lathe without special arrangement or preparation of the bed. It was formerly necessary in nearly every case to have planed grooves or flat surfaces at the back of the bed for this purpose whenever a lathe was to have a taper attachment fitted to, or sold with it; second, to have the attachment so designed and constructed that it may be brought into use or detached with the least possible time and trouble; and third, that

the parts are so constructed as to be as absolutely rigid as possible, particularly against any strain that would tend to throw them out of the predetermined line of inclination.

Among the failures of taper attachments the most common is that of turning a taper so that the inclined line of the surface of the turned piece is curved rather than straight; sometimes convex and sometimes concave. The operator should always use special care to have the attachment perfectly rigid in all its movable parts, clamp screws tight and adjustments perfect; and that *the cutting tool is set correctly at the height of the centers.*

Figure 116 shows a rear view of the taper attachment as

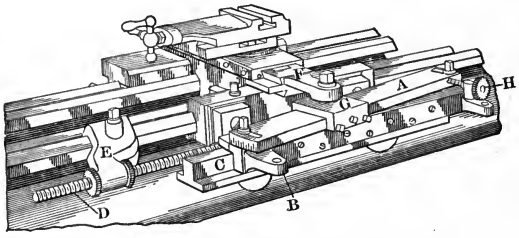


FIG. 116. — Taper Attachment built by the F. E. Reed Company.

designed and constructed by the F. E. Reed Company. The inclined guide-bar A is graduated on the end so as to show the amount of taper that is being turned. This bar is secured to a plate B, which slides upon the bar which is attached to the lathe carriage. The bar A, and plate B, are secured against longitudinal movement by means of the rod D, secured to the bracket E, clamped to the bed.

By this means there need be no special preparation of the bed of a lathe in order to use the taper attachment. The carriage must, however, be of special construction. An intermediate slide E is provided, with its rear end pivotally connected with the sliding block G, which travels upon the inclined bar A and thereby produces the variation of alignment in the travel of the cutting-tool necessary to turn a taper.

The inclined guide-bar A may be minutely adjusted by the screw H, which may be placed as shown, or in the hole shown at B, as may be desired.

It would appear that this attachment would not be of sufficient strength and rigidity to withstand the strain of heavy turning on a very severe taper, and still do accurate work.

The R. K. Le Blond taper attachment is shown in Fig. 117. The slide supporting bracket A is attached to a dovetail formed upon or attached to, the bed. Upon it is swiveled the guiding bar B, upon which is fitted the sliding block C, pivotally connected with the compound rest shoe D, by means of the block E and connection F.

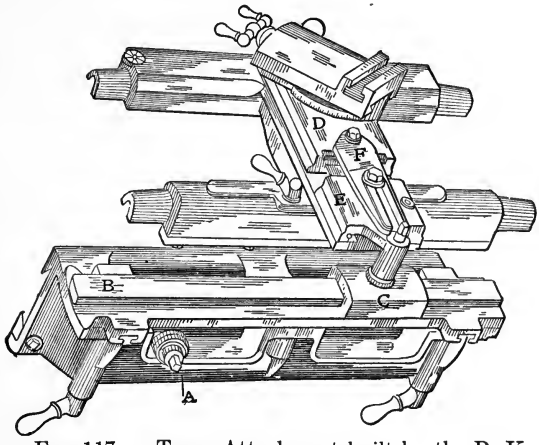


Fig. 117. — Taper Attachment built by the R. K. Le Blond Machine Tool Company.

This taper attachment is of new design, and is very rigid. It is changed from straight to taper work by simply removing a taper pin from one hole to another. The cross-feed nut is never disconnected and the compound rest can be moved by the screw when turning both straight and taper work.

When extra heavy work is done the compound rest can be clamped to the taper attachment by a brace. By this arrangement all thrust is relieved from the screw, insuring greater accuracy. The guiding bar is graduated to taper per foot and is clamped in position by two T-slot bolts. A graduated screw adjustment is provided for accurately setting the bar.

Figure 118 shows the Lodge & Shipley taper attachment. It is constructed in a similar manner to that made by the F. E. Reed Company, as will be seen by the engravings of the two devices.

It is supported by the carriage, and the supporting bar upon which the inclined guide-bar A rests is secured against longitudinal movement by a rod D and bracket E, the latter clamped to the bed the same as in Reed's device.

The taper attachment is extremely simple, and composed of less parts than any in the market. In operation it is changed

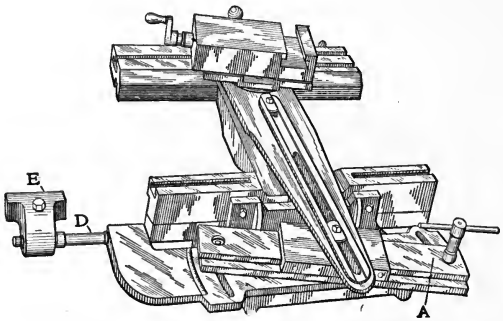


FIG. 118. — Taper Attachment built by the Lodge & Shipley Machine Tool Company.

from straight to taper by tightening or releasing one screw on the dog. When attached for taper work the sliding shoe connects directly with the tool-rest and not with the screw, making its operation instantaneous. The nut is made to release and slide in a groove. The stud for the sliding shoe also engages into a groove, and to attach or detach requires nothing more or less than the releasing of one screw and tightening another, or vice versa.

The cross-feed nut cannot fall over as in ordinary taper attachment when in use, because it is never disconnected. The bolt simply slides in a slot in the compound rest slide.

Figure 119 shows the taper attachment made by the Hamilton Machine Tool Company. Like that made by the R. K. Le Blond Machine Tool Company, this has its supporting bracket carried upon a slide formed upon or attached to the bed. It is thereby rendered very rigid and substantial. The swiveling of the inclined guiding bar is similar to those already described, and the attachment of the connecting block to the cross-feed screw is easily understood by reference to the engraving in which it will be seen that the end of this block passes through the bracket attached to the rear

of the carriage. The sliding block runs in a dovetail in the inclined guide-bar instead of on a square raised rib on top of it.

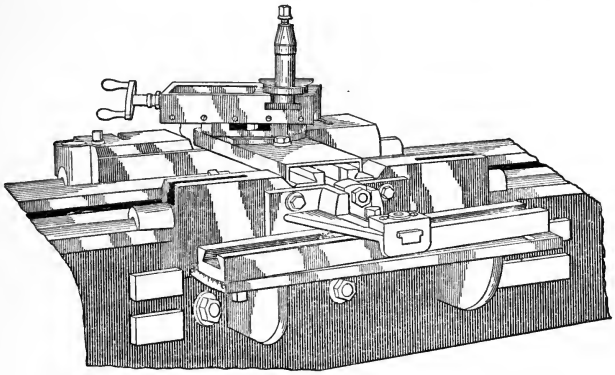


FIG. 119. — Taper Attachment built by the Hamilton Machine Tool Company.

This dovetail form is not at all necessary, as a square form is as good, if not better, and much more economical. There is no ten-

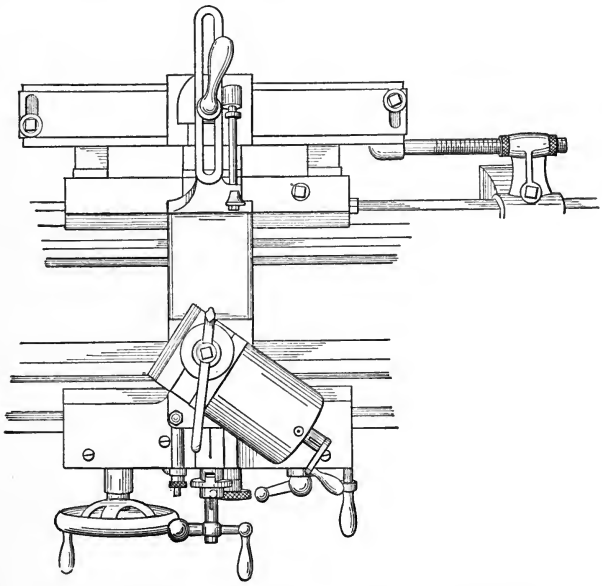


FIG. 120. — Taper Attachment built by the Hendey Machine Company.

dency to lift the block that would make the dovetail form advisable.

The Hendey-Norton Taper attachment is shown in Fig. 120.

It is supported by the carriage as in the Reed and the Lodge & Shipley designs, and travels with it and is therefore always ready for use. All operations necessary to use the attachment are made from the front of the carriage, and consist of first setting the taper bar to any desired degree, binding the sliding bar clamp to the back V, loosening the post screw at the end of the carriage arm which releases the cross-feed screw connecting block, and clamping the connecting link onto the taper-bar slide by means of the binding handle. The top link and the binding bolt, which is fitted to a reamed hole in the head of the block, furnish a double connection (and one that is absolutely rigid) between the two slides, preventing any back-lash.

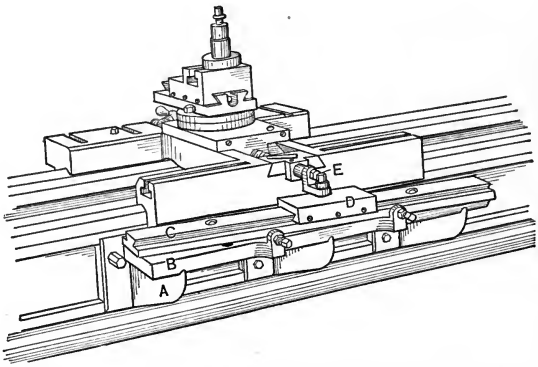


Fig. 121. — Taper Attachment built by the New Haven Manufacturing Company.

Figure 121 shows the taper attachment as made by the New Haven Manufacturing Company. The supporting bracket is adapted to travel in an upper and lower groove planed in projecting ribs on the back of the bed, thus rendering the support very rigid. The plate B is heavy and rigid and supports the swiveling guide-bar C, upon which slides the block D. In the later development of this device the dovetail is replaced by a square projecting rib. There is also an improvement in the connection E with the cross-feed screw, consisting of a heavy flat bar attached to the rear of the compound rest shoe and sliding through a strong and rigid guide block. Its rear end is pivotally connected with the block D, making a very accurate and rigid design.

In all these attachments making use of the cross-feed screw as

an adjusting member, it must be so arranged as to be detachable from its front bearing, or permitted to slide through it so that the inclined movement of the block on the guide-bar may gradually

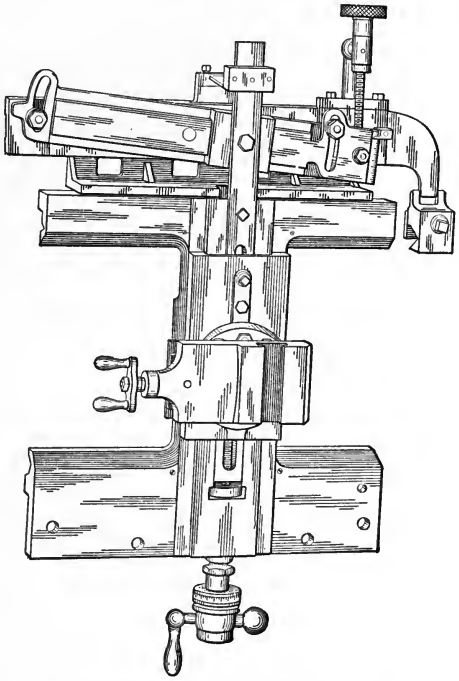


FIG. 122. — Plan of the Bradford Taper Attachment.

work the compound rest forward and back to form the taper as the cut proceeds.

Figure 122 is a plan of the Bradford taper attachment, and Fig. 123 is a cross section of the same device. It is of the type of carriage-

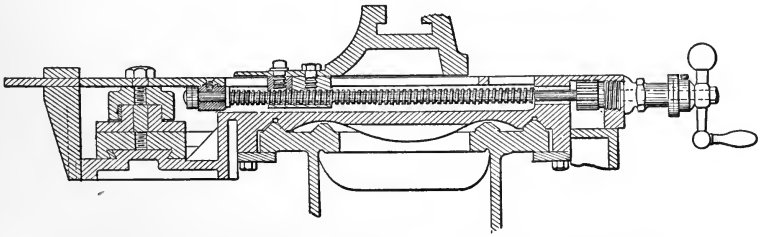


FIG. 123. — Cross Section of the Bradford Taper Attachment.

suspended devices similar to several heretofore shown and described.

From the accompanying sectional view it will be seen that the rear end of the cross-feed screw is held by collars and journaled in a bearing, which is bolted to a bar connecting it with the sliding shoe on the inclined slide, so that the screw always moves with the bar and carries the compound rest with it.

The tool is controlled by the screw at all times without interfering with the handle, the end of the screw telescoping into the sleeve on which is the pinion governing the power feed. Where it telescopes it is splined, and so the screw is under control of the operator, irrespective of the position of the tool due to the taper bar. When turning tapers the lower slide of the compound rest should be tightly clamped to the bar by the square head screw, shown in cut. Consequently there is no disconnecting of any of the parts when engaging or disengaging the attachment. Simply tightening the dog to the ways brings the attachment into service, and loosening the same disengages the attachment, leaving the lathe in proper shape for straight work; and in neither case does the use of the attachment interfere in the slightest degree with the full and complete use of the compound rest, should it be desired to face off a piece the full swing of the lathe.

The construction further makes the attachment of exceptional value on lathes of extra length, in that it is available the full distance between centers by reason of its being bolted to, and traveling with, the lathe carriage.

CHAPTER VIII

LATHE DESIGN; TURNING RESTS, SUPPORTING RESTS, SHAFT STRAIGHTENERS, ETC.

Holding a lathe tool. The old slide-rest. The Reed compound rest. The Lodge & Shipley compound rest. The Hamilton compound rest. The Hendey-Norton open side tool-posts. Quick-elevating tool-rest. The Homan patent tool-rest. The Le Blond elevating tool-rest. The Lipe elevating tool-rest. Revolving tool holder. The full swing rest. The Le Blond three-tool rest. The New Haven three-tool shafting rest. The Hendey cone pulley turning rest. Steady rests. Follow rests. The usual center rest. The New Haven follow rest. The Hendey follow rest. The Reed follow rest. The Lodge & Shipley follow rest. Their friction roll follow rest. Shaft straighteners. The Springfield shaft straightener. New Haven shaft straightener. Lathe countershafts. The two-speed countershaft. Geared countershafts. The Reed countershaft. Friction pulleys. Tight and loose pulleys. Self-oiling boxes. The Reeves' variable speed countershaft. Design of geared countershafts. Another form of variable speed countershafts.

WHILE the old principle of holding a lathe tool in a tool-post or under one or more clamping bars is still largely used to securely hold the tool in a rigid position for performing its work, there have, within the past few years, been designed and come into use a number of very convenient, rigid, and practical tool-holding devices.

The use of high-speed steel, and consequently of heavy cuts, have rendered the use of very rigid tool-holding devices imperatively necessary.

Some of the more prominent of these are here shown and their special features commented upon.

The old familiar slide-rest of our apprenticeship days still lives and is much used on hand lathes, bench lathes, and the like. Fig. 124 shows this form of turning rest as made by the F. E. Reed Company. Its construction is so familiar to every mechanical man that any description is unnecessary.

Figure 125 shows a very efficient compound rest made by the same establishment to which attention is called as to the very rigid method of holding and clamping the tool by two heavy clamping

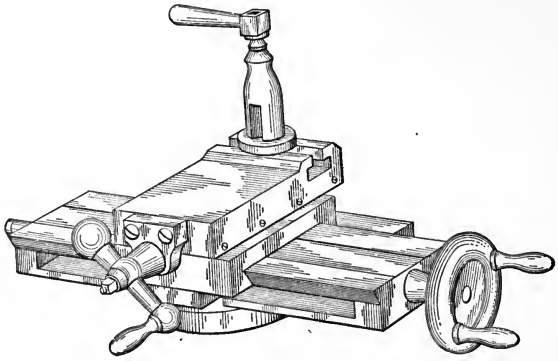


FIG. 124. — Plain Slide-Rest, made by the F. E. Reed Company.

screws. Also to the important fact that the tool is held at the extreme left-hand edge of the tool-holding device, in which position it is nearly always used. At the same time the entire top, tool-holding block is adapted to turn in any direction and to be securely held at any angle, thus making it invaluable for turning up

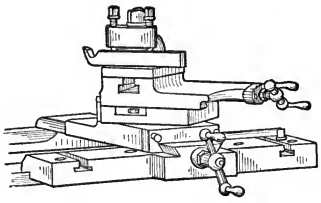


FIG. 125.—Compound Rest made by the F. E. Reed Company.

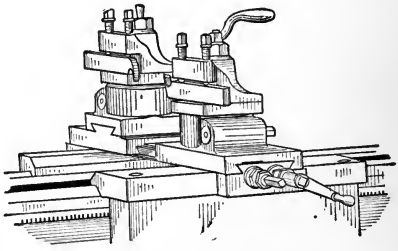


FIG. 126. — Compound Rest for Two Tools, made by the F. E. Reed Company.

to close shoulders or other obstructions at the *right*, and also when turning or boring inside work wherein it is necessary to set the tool nearly parallel to the center line of the lathe.

Figure 126 shows a similar device, made by the same company, with arrangements for holding two tools under the same conditions

as above noted. This is very useful when heavy cuts are to be made upon work where rapid reduction of the amount of stock is called for, as the inverted back tool assists very much to balance the resistance by dividing it between two points.

Figure 127 is of the compound rest and tool-holding device as made by Lodge & Shipley. It is neat and substantial and the forward prolongation of the shoe adds rigidity on heavy cuts. Both the upper and lower slides are fitted with taper gibs, which, besides being tapering, are tongued and grooved into the slides, so that no amount of strain will displace them. These gibs are provided with two screws only, and at each end, which take up the wear evenly the entire length, and are possible of delicate adjustment. They will not require resetting perhaps more than once a year.

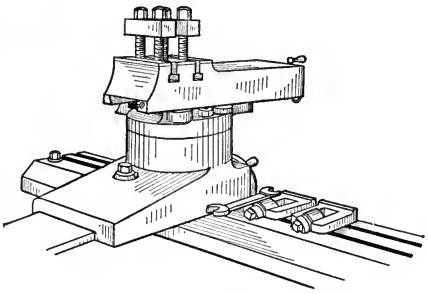


FIG. 127.—Compound Rest and Tool-holding Clamps made by the Lodge & Shipley Machine Tool Company.

The-tool clamping bars are arranged the same as those of the New Haven device, shown in Fig. 114. These slide loosely into the T-slots and may be removed and replaced by the arch clamps shown at A, A, the tool passing through one or both of these as occasion may require. They may be located at any desired position in the T-slots. This alternate device will be found very convenient on many unusual jobs as well as upon regular work.

In Fig. 128 we have the compound rest with its tool-clamping device as made by the Hamilton Machine Tool Company. It is quite similar to that shown in Fig. 124, and made by the F. E. Reed Company, and possesses its good advantages of adjustment of the tool to point in any direction and to work up closely to a shoulder on either side. Lodge & Shipley make a similar device with the tool clamp almost identical with this one.

Figure 129 shows the "open-side tool-post" made by the Hendey Machine Company. It is so arranged that it may be substituted for the slotted tool block and ordinary tool-post of their lathes. It may be swiveled to any desired angle and accurately adjusted

by the graduations at the base. It is a good example of a rigid and substantial tool-holding device.

Figure 130 shows the "quick-elevating" tool-rest made by the same company. The tool is raised or lowered by using the tool-post wrench on the short lever indicated in front in the engraving. It carries the old-style tool-post and is not, therefore, as rigid as that shown in Fig. 128.

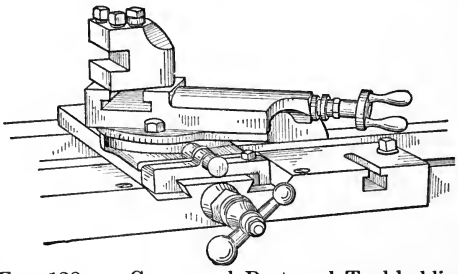


FIG. 128. — Compound Rest and Tool-holding Device, made by the Hamilton Machine Tool Company.

Figure 131 shows the Homan patent tool-rest, which is also made by the Hendey Machine Company, which has a screw adjustment as to height and a graduated base for setting to any required angle. It is, perhaps, the most rigid device of the kind using a

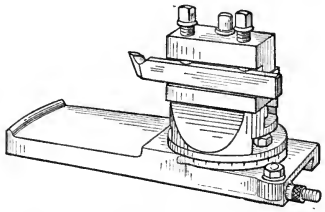


FIG. 129. — Open Side Tool-Post, made by the Hendey Machine Company.

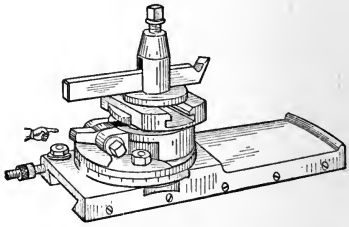


FIG. 130. — Quick-Elevating Tool-Post made by the Hendey Machine Company.

single tool-post, and is a very well made, accurate, and convenient piece of mechanism.

In Fig. 132 is represented the Le Blond elevating tool-rest provided with a thread-chasing stop which is clamped to the dovetail upon which the rest slides. The device is very simple and effective

for ordinary work. It would not seem quite so well adapted, however, for very heavy cuts on account of the fact that a heavy vertical strain would be rather severe on the inclined screw which holds the tool block up to its position.

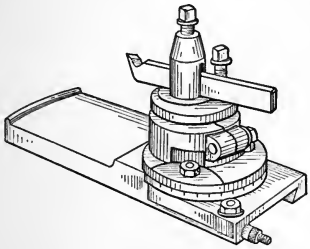


FIG. 131. — The Homan Patent Tool-Rest made by the Hendey Machine Company.

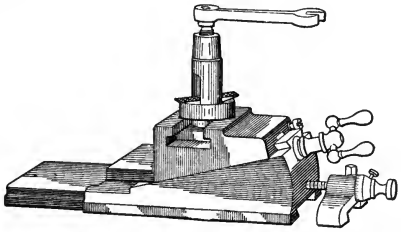


FIG. 132. — Elevating Rest with Thread Chasing Stop, made by the R. K. Le Blond Machine Tool Company.

A very substantial device is shown in Fig. 133, and known as the Lipe elevating tool-rest. It is made by the Lodge & Shipley Machine Tool Company. In this device the tool-holder proper has formed upon its lower end a cylindrical portion which fits into the main casting and is secured thereto in any desired position by a strong clamping screw. It is adjusted vertically by a screw through the upper, and bearing upon the lower casting as shown in the engraving. The entire device fits upon the dovetail of the carriage in place of the compound rest. This device is as rigid as is possible to make an adjustable tool-holding device and is amply strong for heavy cuts.

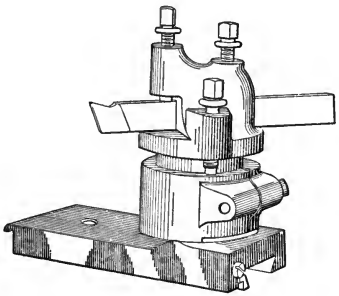


FIG. 133. — The "Lipe Elevating Tool-Rest," made by the Lodge & Shipley Machine Tool Company.

The revolving tool-holder, shown in Fig. 134, is made by the Lodge & Shipley Machine Tool Company, the R. K. Le Blond Machine Tool Company, and others. It is a very useful form and is equally adaptable to the carriage of an engine lathe or the slide of a turret lathe.

It is a very strong and rigid device and holds four tools, either at the corners or sides. The locking pin withdraws automatically

when the clamping bolt is released to revolve the turret. It is interchangeable with the compound rest, simple in design, rigid in construction, and a great time-saver where the number of pieces reduced to the same dimensions permits the several tools in the tool-post to be used alternately.

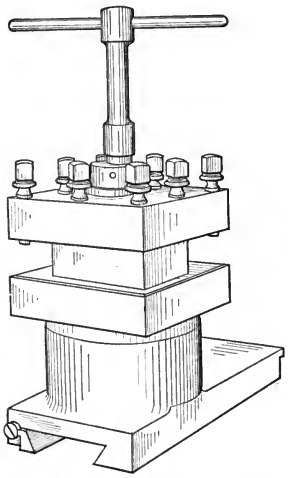


Fig. 134. — Revolving Tool-Holder, made by the Lodge & Shipley Machine Tool Company.

Its greatest advantage seems to be that by its use we practically add the features of a turret to the ordinary engine lathe and at a very nominal cost. It is true that we do not get the drilling and reaming features, but still many turret operations may be accomplished by its use.

Figure 135 shows what is variously termed as a "full swing rest," or a "pulley rest," or a "wing rest," etc., by different lathe builders. First, because it is for turning work the full swing of the lathe and which the tool in the compound rest will not conveniently reach; second, because it is principally used for turning pulleys, and work of that nature, and third, because it is attached to the front "wing" of the lathe carriage.

It is frequently made at an angle, inclining downward from the center of the lathe so that it may be made conveniently low to fit the low carriage of a large swing lathe and still have the general line of the tool on a radial line from the lathe center. This rest is practically the same as the plain tool block used on the carriage, with a base suitable for bolting down over a T-slot.

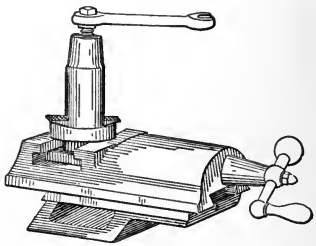


Fig. 135. — Full Swing Rest made by the R. K. Le Blond Machine Tool Company.

Figure 136 represents a three-tool turning rest, adapted to be used on ordinary engine lathes. It is made by the R. K. Le Blond Machine Tool Company.

It consists of a special base or slide, carrying three tool-holders, two in front and one in back. These may be advanced towards each other simultaneously by means of the cross-feed screw, in addition to which each has an independent forward and backward movement. The rear tool-holder has also lateral adjustment. The base is surrounded by a groove for collecting the oil, soda-water, or other lubricant used. The device is invaluable for many purposes.

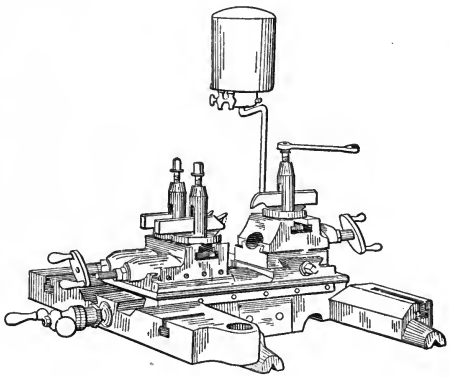


Fig. 136. — Three-Tool Turning Rest, made by the R. K. Le Blond Machine Tool Company.

Figure 137 shows the three-tool shafting rest made by the New Haven Manufacturing Company. This is adapted to be located on the carriage of an ordinary engine lathe in place of the compound rest, and in addition to the three-tool slides, tool-posts, etc., in the

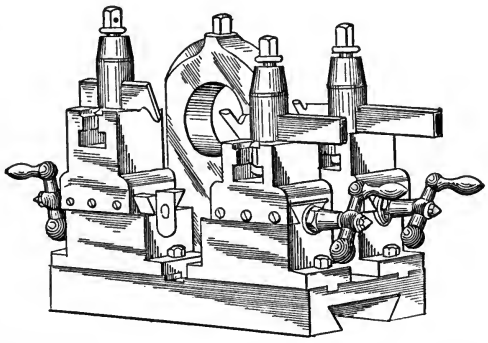


Fig. 137. — Three-Tool Shafting Rest, made by the New Haven Manufacturing Company.

last example there is a fixed standard in the center providing a center rest in which bushings of various diameters, to suit the different sizes of shafting, may be carried, and which serve to hold the shafting to be turned steady and firm for the action of the turning tools. In the last example this function must be

performed by a separate "steady rest," attached to the carriage or to the lathe bed.

The turning of cone pulleys is usually a tedious and expensive job unless some special device is in use for the purpose. In Fig. 138 is shown such a device built by the Hendey Machine Tool Company. It should of necessity have a special carriage to accommodate it. The center part of the carriage should be as wide as the length of the largest cone to be turned in order to have ample support for the end tools. The tool-carrying block is adapted to swivel so as to accommodate the locations of the tools to the varying diameters of the cone, as the difference between the diameters of the smallest and largest steps will necessarily vary considerable.

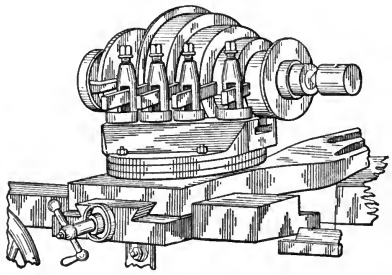


FIG. 138. — Cone Pulley Turning Rest, made by the Hendey Machine Company.

As one T-slot holds all the tool-posts it is only necessary to provide as many tool-posts as there are cone steps.

The crowning of the pulley faces is effected by a taper attachment device, or its equivalent, at the back of the carriage. This may be effected by using straight tapers and making two settings, the inclined lines meeting in the centers of the pulley faces; or, the proper curve or "crown" may be given to the device by a curved guiding bar instead of a straight one.

Under the general name of steady rests we may include any attachment to a lathe which has for its purpose or function that of furnishing a support at one or more points around the circumference of the piece being turned, opposing the pressure of the cutting edge or point of the tool and holding the work up to its original position and alignment as before the tool commenced cutting.

Ordinarily there are two classes of these rests which may in a general way be called "center rests" and "back rests." The center rests usually have jaws bearing upon the work at three points spaced equally around the circle, while a back rest bears upon the work generally at the back and on top only. Sometimes such a rest

consists essentially of a forked or V-shaped piece firmly held and embracing the circle of the work.

Sometimes these rests are attached to the carriage and follow the work of the cutting-tool closely so as to continue the support given the work as near the tool as possible. These are often called "follow rests." They may be made with two or three adjustable jaws resting against the work, or they may carry a bushing having a hole reamed just large enough to admit of passing rather closely over the work, sometimes in advance of the work (in case of previous turning), but usually following the tool.

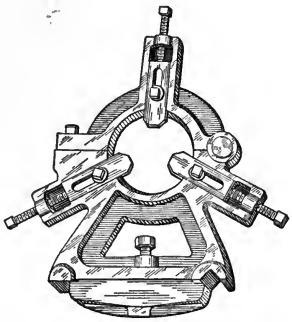


FIG. 139. — Center Rest, as made by nearly all Builders.

Figure 139 is of the well-known form of a center rest, substantially as made by all lathe builders, the variations of design being in matters of detail, and not in general form, functions or methods of support or attachment.

Figure 140 is of the follow rest as made by the New Haven Manufacturing Company. It will be noticed that the top jaw inclines to the front, so that, acting in conjunction with the back and the bottom jaw, it serves to embrace more than half of the circle of the work in the process of turning. The base of this rest is fitted to the dovetail on the lathe carriage and fits in behind the compound rest.

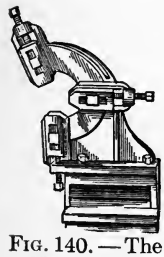


FIG. 140. — The New Haven Follow Rest.

Figure 141 represents the Hendey follow rest for use on light lathes. It is bolted to the side of the carriage and "steadies" the work by means of the adjustable jaw which is set up against the back and top of the piece to be turned, and held in that position by two set-screws as shown.

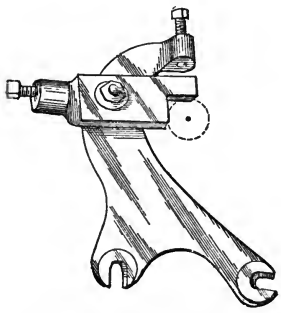


FIG. 141. — The Hendey Follow Rest.

In Fig. 142 we have the follow rest used by the F. E. Reed

Company. This rest has but two jaws, one at the rear and one over the work. Its peculiar feature is that the jaws may be removed and a special piece substituted, which is bored out to receive bushings which may be bored and reamed to fit the different sizes of work to be machined. This feature will prove advantageous, particularly when a large number of parts, say shafts, are to be turned.

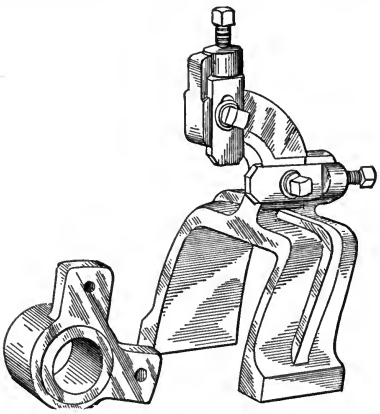


FIG. 142. — The Reed Follow Rest, with Bushing.

Figure 143 represents a very solid and substantial follow rest made by Lodge & Shipley Machine Tool Company. It is adapted to very heavy work and will be found useful on any rapid-reduction lathe. With one exception it is the strongest follow rest made.

Figure 144 shows the strongest follow rest made and is a product of the same establishment. Being provided with friction rolls for reducing the friction of the work, it is adapted to the heaviest work the lathe is capable of carrying. It is well designed for the purposes for which it is to be used and its parts are so made as to be easily adjustable to suit the work. Its special points of construction are interesting as showing the thoroughness of the design.

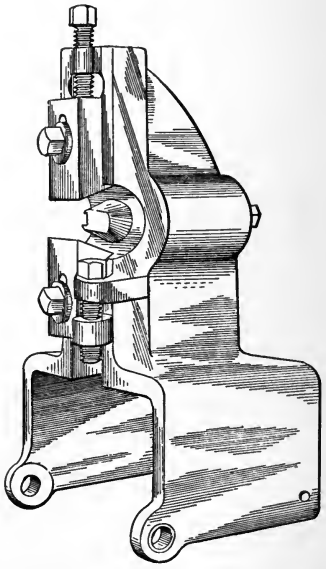


FIG. 143. — The Lodge & Shipley Follow Rest.

The two jaws carrying hardened-steel rollers move in and out in a circular path, being actuated by a worm and knob. When set in any position they are adapted for a variety of diameters by simply moving the entire rest backward or forward. This is accomplished by connecting

the rest to a screw which telescopes the regular cross-feed screw and is operated by the same hand wheel which sets the tool-rest. The position of the rollers is such that in approaching a shoulder they support the shaft upon the smaller diameter until the cutting-tool has turned a portion of the next larger diameter, when the position of the rest is changed to bear on that portion.

Those having quantities of shafts, with a number of shoulders to turn, will recognize in this rest an attachment entirely new in principle and of the greatest importance in the saving of time.

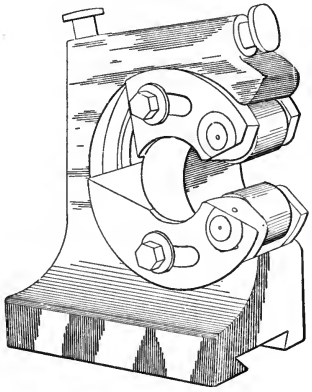


Fig. 144.—The Lodge & Shipley Special Roller Follow Rest.

One of the indispensable accessories or attachments, if it may be so called, to an engine lathe, particularly one provided with a long bed, is some kind of a "straightener," by which not only rough bars of stock, but partly finished and finally entirely finished shafts, may be straightened.

The general plan of doing this work is to rest the shaft upon two points at some distance apart and then apply pressure on the opposite side, and at a point midway between these two points.

These attachments or accessories are sometimes attached to the carriage of the lathe; sometimes mounted so as to slide on the V's of the lathe; again upon wheels that run in the space between the inner and outer V's; and in still other cases, for small and comparatively short work, they are mounted upon a bench. In this case they either have attached to them a pair of centers in which the work to be straightened may be placed and its correctness or incorrectness as well as the location and extent of the inaccuracies may be determined, or a pair of V-blocks in which the shaft may be laid while being straightened.

In Fig. 145 is represented one of the latter forms of this accessory made by the Springfield Machine Tool Company, the uses of which will be readily understood by any mechanic. It is intended to be placed upon a bench and to be used when centering work by hand, and for straightening work centered by hand or machine.

It is a familiar fact that work straightened in a press is more likely to remain straight in the lathe than when hammered straight, and that it is better in every way.

The general arrangement of this machine is in itself very convenient, as any work within its range of centers may be tested and straightened without the unnecessary walking from press to lathe each time in straightening rough or finished work. This, however, does not limit the length of shaft that can be straightened, as any length may be operated upon, thus making it a great labor saver.

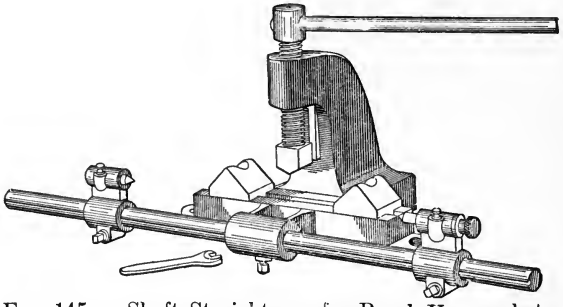


FIG. 145. — Shaft Straightener for Bench Use, made by the Springfield Machine Tool Company.

In the tool-room it is especially valuable, not only for centering and straightening work in the rough, but for straightening pieces which have been accidentally sprung in use, or reamers, etc., which have been sprung in tempering.

The blocks upon which the work rests when being straightened are removable to or from the screw and are kept in line by tongues, which fit the groove shown. The shaft is movable through the arm which supports it, being held in any desired position by the set-screw shown, which has a piece of brass over its points to avoid marring the shaft. The centering heads are clamped in any desirable position on the shaft, by the binding screw shown. The top of the arm which supports the shaft forms a pocket for chalk or other material used in marking.

The center at the right is pressed forward by a spring and has a knurled head for drawing it back, both centers being provided with small oil wells. The body of the machine has three lugs cast upon it, by means of which it is bolted to the bench. The block

which is on the end of the screw is of cast steel, case hardened, and the centers of tool steel tempered — the whole machine being so designed and constructed as to make it worthy of a place and useful in any tool-room or machine shop where much small work is done.

Figure 146 shows the shafting straightener made by the New Haven Manufacturing Company. The base A has cast upon it at the rear a curved standard B, made very strong by proper ribs and extending over to the front. Through the top of this passes a vertical compression screw C, running in a long bronze nut and carrying loosely upon its lower end a V-block D, adapted to fit

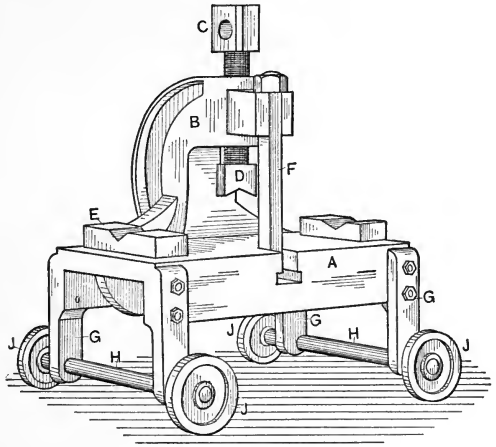


Fig. 146. — Shaft Straightener for use on Lathe Bed, made by the New Haven Manufacturing Company.

down upon the round shaft, which is laid into two other loose V-blocks E, E. To insure great rigidity when handling large work the forged stay rod F is provided, its head being held in a T-slot in the base casting and its upper end in a slot cast in the head and in front of the compression screw C, and secured by a heavy nut.

At each corner of the base casting is bolted a leg G, G, G, G, carrying loosely journaled therein the shafts H, H, on the outer ends of which are fixed the wheels J, J, J, J, which are adapted to run in the spaces between the inner and outer V's of the lathe bed, which permits it to be moved to any point where its use may be desired.

In ordinary cases a countershaft is a very simple mechanism. In the older form of engine lathes all that was necessary was a cone pulley identical with the spindle cone, and upon the other end of the shaft a tight and a loose pulley for receiving the driving-belt from the pulley on the main line shaft. Then, as threads required a backward motion of the lathe spindle, a second pair of pulleys was added and a cross-belt applied for that purpose. The shifting of these belts was too slow for practical work and clutches were used. These were of the old "horn clutch" type, making considerable "clatter" in their use and starting the work with too much shock.

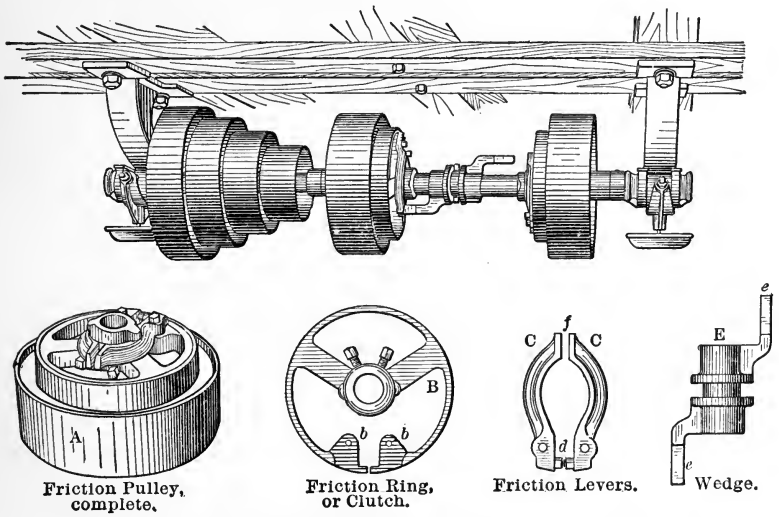
Later on friction clutches or friction pulleys were devised, and these in one form or another are largely in use at the present time.

Up to a comparatively recent date the lathe had but two speeds, so far as the countershaft controlled it. One was the usual forward speed, the other a considerably faster speed backwards, mostly used in thread cutting. Occasionally, for special work, this "backing" speed was taken advantage of by changing the cross-belt for an "open belt," and thus getting another range of speeds. Doubtless this suggested the advantages of a regular two-speed countershaft which has now become quite common, as a convenient and economical method of adding another series of speeds to the lathe.

There are now used on a number of popular lathes geared countershafts as well as various devices for producing a variable speed by a *gradual* increase or decrease of the number of revolutions per minute. This result has been sought by a number of different devices with more or less success. Some of them have had good features to commend them while others were more in the line of makeshifts that accomplished the results sought very inefficiently and partook too much of the nature of "traps" as understood by the machinist, and hence were comparatively short-lived and unpopular.

Figure 147 shows a good example of the regular type of lathe countershafts. It is made by the F. E. Reed Company, and consists of the cone pulley, a counterpart of the spindle cone part, and two friction pulleys mounted upon the shaft, which is supported in two hangers having self-oiling boxes. The friction pulleys consist of

the pulley proper A, which is turned on the inside of the rim for the reception of the friction band B, or has cast with it a rim projecting from the pulley arms and finished inside for the same purpose, as shown in the engraving. The friction band B is divided at one point as shown, the two loose ends having projecting lugs at *b*, *b*, drilled for pivot bolts by which it is connected with the levers C, C, whose ends are adjustably connected by the screw and nuts shown at *d*.



Friction Pulley, complete. Friction Ring, or Clutch. Friction Levers. Wedge.

FIG. 147. — Friction Countershaft for Engine Lathes, made by the New Haven Manufacturing Company

Sliding upon the shaft between the pulleys is the clutch collar E, whose horns *e*, *e*, are adapted to enter between the ends of the levers C, at *f*. These horns being wedge-shaped will, when thrust between the free ends of the levers C, C, spread them apart, and as their fulcrum ends are connected, and by means of the pivot bolts connected to the free ends of the friction band B, tend to extend the opening of this band, enlarge its diameter, bring it in contact with the inner surface of the pulley (or of the rim cast upon it for that purpose), and cause sufficient friction to transmit the required power.

The clutch collar or sleeve E is provided with a square groove at its center to accommodate the shipper fork, by means of which

it is moved to and fro on the shaft, according as one or the other clutch is to be thrown into an active position and the lathe to be driven by the belt on the one or the other pulley. One of the pulleys carries an open belt and the other a cross belt.

There are various forms of friction pulleys and friction clutches used on countershafts, but all are designed with analogous parts to the above and perform similar functions. Therefore there is no need for a detailed description and illustration of them. In all of them the pulleys run loose on the shaft, except when clamped to it by means of the friction device, the disc or friction band B, or its equivalent, being fixed to the shaft.

In the center of the shaft between the pulleys is usually a sliding sleeve that operates the friction mechanism, as here shown, and by which it is connected to the shipper lever within easy reach of the operator.

The tight and loose pulleys are still used on very heavy lathes, and in this case, when both the forward and backward motion is desired, there is one tight pulley a little greater in width than the belt, and on each side of it a loose pulley of double this width. The

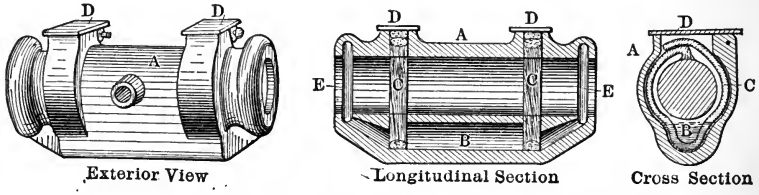


FIG. 148. — Self-Oiling Boxes for Countershafts, made by the F. E. Reed Company.

belts are so located that each is on one of the loose pulleys when the shipper handle is in its middle position. When it is moved to the right of this position the left belt is moved on to the tight pulley and the right belt travels to the right on its loose pulley. By moving the shipper handle to the left the reverse effect is produced, and the right-hand belt becomes operative. The pulley on the line shaft is, of course, as wide as all three on the countershaft.

In Fig. 148 is given a good illustration of the self-oiling countershaft box, which is used on the countershaft shown in Fig. 146.

As will be seen by the engraving (Fig. 147), the journal box A

has formed beneath it an oil reservior B for holding a quantity of oil sufficient to last several weeks. Near each end is a groove containing a wick or strip of felt C, C, surrounding the shaft and reaching down into the oil reservoir B, by means of which an ample supply of oil is always delivered to the journal bearing. The wick may be introduced and oil supplied by opening the hinged covers D, D.

As the supply of oil is so profuse there is the liability of waste by its running out at the ends of the journals. This is prevented

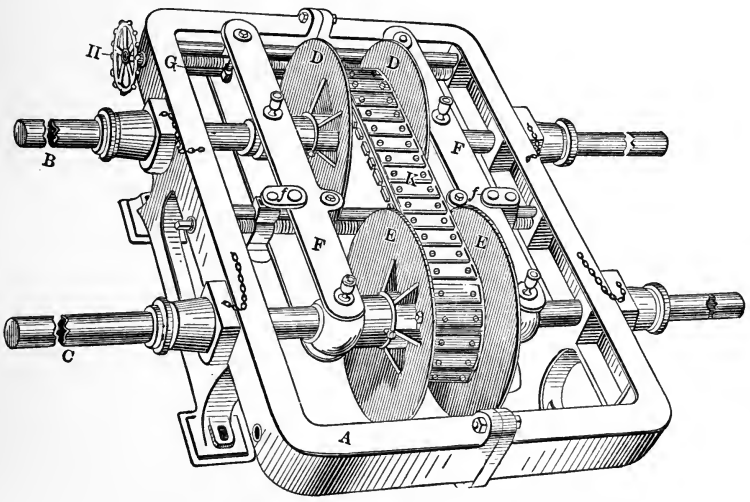


Fig. 149. — Reeve's Variable Speed Countershalft.

by providing the return oil grooves E, E, at the ends, which conduct the oil back to the oil reservoir. The design and arrangement is very simple and at the same time very effective. It is used with slight modifications for many similar purposes with like success.

In Fig. 149 is shown the Reeves' variable speed countershaft, which has proven a valuable device when the speeds required are not excessive. It is well adapted to nearly all machine-shop tools and by its use a great range of speeds may be obtained.

It consists of two shafts B and C, journaled in the frame A, in the usual manner. Upon the shaft B is splined the rather flat cones D, D, and similarly connected to the shaft C are the cones E, E. These cones are adapted to slide freely to or from each other on

their respective shafts, and their movement is governed by the levers F, F, which are fulcrumed at *f*, *f*, and pivotally attached to the hubs of the cones D, D, E, E, by suitable collars. The farther ends of these levers are pivotally connected to a screw G, by suitable nuts running on right and left threads, whereby the nuts may be drawn together or forced apart as may be necessary, carrying with them the ends of the levers F, F, and consequently the cone discs D, D, E, E, but by an opposite movement; that is, as the discs D, D, approach each other the discs E, E, recede from each other. Upon the end of the screw G is the sprocket-wheel H, from which a chain runs to another sprocket-wheel near the operator, who may handle it by means of a crank upon the shaft of the latter wheel.

Running within the cone discs D, D, at one end, and E, E, at the other, is a series of wooden lags connected by a chain mechanism by which it becomes in effect a belt, the ends of the lags bearing against the inner, inclined surfaces of the cone discs.

The length of the wooden lags being constant, it follows that as the cone discs are forced closer together the lags will ride up on a larger diameter, and simultaneously the cone discs on the opposite shaft will, by the mechanism described, be drawn farther apart, permitting the lags to run closer to the shaft and on a correspondingly smaller diameter.

Now, as one of the shafts B, C, is driven by a belt from a pulley upon the main line shaft, while the other carries the pulley (in this case a cone pulley) driving the machine, the speed of the same may be varied at will, as one pair of cone discs are forced nearer together and the other pair farther apart, thus, in effect, changing their relative diameters and consequently their speeds.

Geared countershafts are also used upon lathes for producing variable speeds. They depend, of course, upon the usual methods of bringing into active operation pairs of gears of varying diameters by means of clutches, sliding gears, and similar devices. The noise of the gears is one great objection to their use. This has been partially avoided, or smothered, by enclosing them with a casing, which partially obviates another objection, that of throwing oil and dirt upon the floor, the machines, and the workmen.

Another form of variable-speed countershaft was brought into use some years ago which consisted of two comparatively long

cones placed side by side but in reverse positions so that their adjacent sides were parallel. They were mounted upon parallel shafts, one being the driven and the other the driver. Motion was transmitted from one to the other by means of a short endless belt running between the surfaces, with the slack end hanging below them. This belt was controlled by a sliding belt guide by means of which it could be moved from end to end of the cones, whose varying diameters at the point of contact determined the speed transmitted from one shaft to the other.

While this device was entirely operative and, with light loads, reasonably successful, it was not well adapted to transmitting any considerable amount of power, owing to the very small area of contact surface between the cones and the belt, the pressure upon which had to be excessive in order to transmit the power required even for light work.

Unusually large cones would no doubt have added materially to its transmitting power, but as a practical mechanism it was not the success that its admirers hoped it would be.

CHAPTER IX

LATHE ATTACHMENTS

Special forms of turned work. Attachment for machining concave and convex surfaces. Attachment for forming semicircular grooves in rolling mill rolls. Device for turning balls or spherical work. Turning curved rolls. A German device for machining concave surfaces. A similar device for convex surfaces. Making milling cutters. Backing off or relieving attachment. Operation of the device. Cross-feed stop for lathes. Grinding attachments. The "home-made" attachment. Electrically driven grinding attachment. Center grinding attachment. Large grinding attachment. The Rivett-Dock thread-cutting attachment.

WHILE an engine lathe will readily turn straight and taper work, and will "face" work at right angles to the center line of the lathe, or by means of the compound rest will turn or face at any angle, no means is provided for turning curved contours, as spheres, curved rolls smallest in the center, or largest in the center, as the case may be, or to "face up" convex or concave surfaces. These and many other forms must be made by the aid of some kind of a device built for the special purpose and usually known under the general name of a "lathe attachment."

There are, of course, a great variety of jobs that can be economically performed on a lathe if we are provided with the proper tools and a suitable "attachment" for handling them.

It is not proposed to give here a complete list of these ever varying kinds or types of lathe attachments or to exhaust the list of forms of work that may be machined by one or another of these devices, yet it may be interesting to present a few of the attachments that are most likely to be needed, and in a general way those that the machinist may easily make for himself.

It often happens that a large number of concave or convex sur-

faces have to be machined to accurate spherical forms, the pieces being of such dimensions or material that the usual forming tools are impractical, or that the variety of dimensions would render them too expensive.

In these cases a special device must be designed which will properly fulfil the conditions and be capable of adjustment within a reasonable range of diameters of the work and the radii of the curves to be machined.

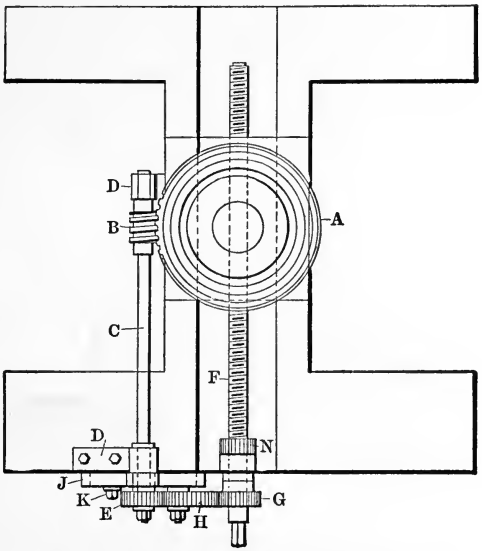


FIG. 150. — Plan of Lathe Attachment for Forming Concave and Convex Surfaces.

This may be accomplished by a special device attached to almost any ordinary lathe having a compound rest with a circular base, such as are now nearly always designed and built. The author has had occasion to design several of these devices, and the general form and arrangement of them has been as shown in the accompanying engravings, in which Fig. 150 is a plan of the lathe carriage showing the circular feeding device; Fig. 151 is a front elevation showing the method of varying the feed to suit the material to be machined; and Fig. 152 shows a modification of the device for a different form of work.

The various forms of work required to be done by a device of

this kind are most frequently for concaving vertical step bearings of various diameters from three inches up, and of radii varying in proportion, for forming concave and convex surfaces for ball and socket joints, for turning large spherical surfaces, and for forming semicircular grooves in rolls for rolling iron and steel bars.

The construction and application of this device, as arranged on an ordinary lathe, is as follows. A machine steel ring A is forged, turned up, bored to a force fit to the circular portion of the compound rest. Its outer surface is properly formed for a worm-gear, its teeth cut and hobbed and it is forced on, and pinned if thought necessary. Engaging the teeth of this is the worm B, fixed to a shaft C, journaled in the brackets D, D, which are fixed to the carriage as shown. Upon the front end of the shaft C is the gear E,

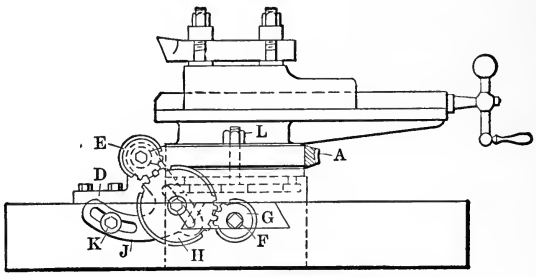


Fig. 151. — Front Elevation of Attachment.

which may be removed and another size substituted for varying the rate of feed. Upon the front end of the cross-feed screw F is fitted a removable gear G. Connecting the gears E and G is the intermediate gear H, carried upon a movable stud located in the stud-plate J, which is pivoted upon a projecting sleeve formed upon the front bracket D and held in any desired position by the clamping screw K. By this arrangement the rate of feed may be conveniently changed to suit different diameters of work and materials of varying degrees of hardness, the same as the usual change-gears of a lathe. By releasing the stud-plate J, the gears G and H may be thrown out of engagement temporarily, while the stud-plate J and the brackets D, D may be easily removed altogether, if it is desired to use the lathe for ordinary turning for any length of time.

As the feed for this device is derived from the cross-feed screw

F, it is necessary to replace the usual solid nut in the shoe by a split nut (not shown) with the usual lever or eccentric device for opening and closing it as may be desired. A clutch device on the front end of the cross-feed screw F may be adopted, if desired, by having the cross-feed pinion N formed upon a sleeve projecting through to the front of the carriage and the gear G mounted upon it, and connected with, or disconnected from, the cross-feed screw F by sliding a double-faced clutch.

In using this device for concave work held in a chuck or strapped to the face-plate, care must be taken to have the compound rest so adjusted on the carriage that when set parallel with the center line of the lathe its center will be exactly under that line, and that the horizontal distance from the point of the tool to the center of the compound rest will be the exact radius of the curve to be produced.

If convex work is to be done the compound rest tool block must be drawn back far enough past the center to give the required radius of the convex curve.

Figure 152 shows a compound rest tool block arranged for forming the semicircular grooves in rolling mill rolls. In this case the tool-post M may be made in two or more sizes, as some of the grooves are small enough to necessitate quite a small tool-post. If a lathe is to be used exclusively for this work the compound rest may be removed entirely and a circular base provided, having worm-gear teeth cut in its edge. This will be held down in the same manner as the compound rest, and have fixed in a raised central portion tool-posts proper for the work for which it is designed. In any event it will be found necessary to construct the device in as strong a manner as possible, in order to prevent, as far as may be the chatter or vibration of the tool.

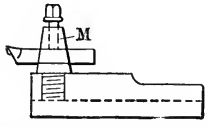


FIG. 152.—Compound Rest of Attachment.

The device as shown will be found to be economical to make and apply, as well as very convenient and efficient in its operation.

All machinists who have ever undertaken to turn balls or partially spherical surfaces know how difficult it is to produce a satisfactory piece of work, either as regards finish, time required, or

accuracy. In Fig. 153 is shown a compound rest containing an attachment for doing this work. In Fig. 154 is a bottom view of the same for the purpose of showing the operative parts.

In its operation the lower slide or shoe A of the compound rest is fixed to the carriage. The cross-feed nut B is fixed to the rack

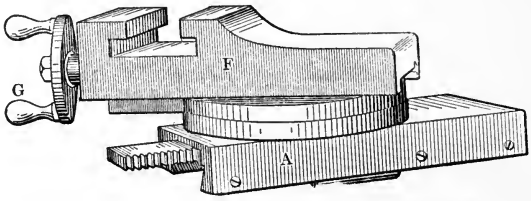


FIG. 153. — Side Elevation of Ball Turning Attachment.

C, which engages with the idle pinion, D, which in turn engages the gear E, which is fixed to the central stem of the compound rest tool block F.

When in use the cross-feed is connected and started, and instead of moving the entire compound rest across the carriage as it ordinarily would, it moves only the rack C forward or back, which motion, being transmitted by the pinion D, and gear E,

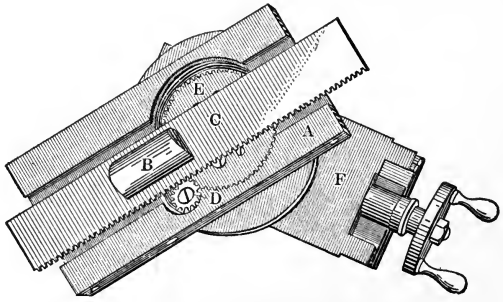


FIG. 154. — Bottom View of Ball Turning Attachment.

swings the compound-rest tool block F around on the center of the gear E, the shoe A being fast to the carriage.

The diameter of the work is regulated by the ordinary compound rest screw crank G, in the usual manner.

The turning of curved rolls such as shown in Fig. 155 is not pro-

vided for in the ordinary attachments sold with an engine lathe, and where this work is not done regularly so as to warrant the designing and building of an attachment for the purpose, some mechanism must be arranged for doing the work.

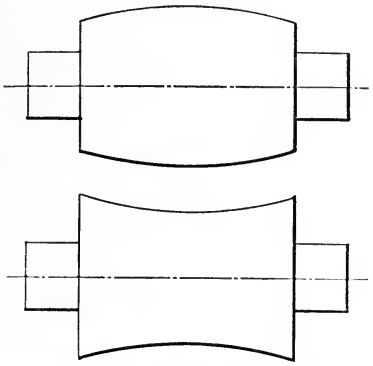


Fig. 155. — Forms of Convex and Concave Rolls to be Turned.

The engravings in Fig. 156, which is a cross section, and Fig. 157, which is a plan, show how an ingenious machinist managed to do this.

In the engravings, A is the bed of the lathe, B is the carriage, and C the compound rest. The curved bar D is attached to the bed by means of suitable brackets at each end, as shown in Fig. 157. This bar is made exactly to the curve which the rolls are to have, both on its concave and its convex edges, and serves as a guide for moving the compound rest forward and back so as to produce the proper curve in its travel across the work.

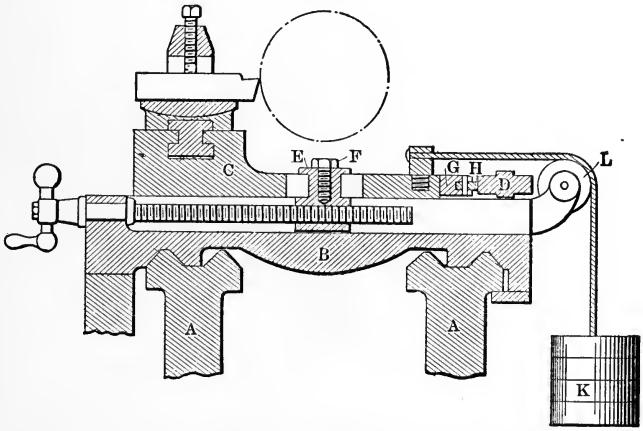


Fig. 156. — Cross Section of Attachment for Turning Convex and Concave Rolls.

To accomplish this travel the cross-feed screw nut E travels in a slot in the compound rest and may be fixed at any point therein by the screw F. Fixed to the rear end of the compound rest shoe

C is a bracket G, in which is pivoted the small friction roller H, which bears against the edge of the curved former bar D. Attached also to the compound rest is the weight K, by means of a cord which runs over a sleeve L, attached to the lathe carriage.

In the use of this device the clamp screw F is tightened up so as to fix the cross-feed screw nut E in its place and the rough forging for the roll turned down nearly to the finish size and form in the usual manner. The clamp screw F is then loosened and the fric-

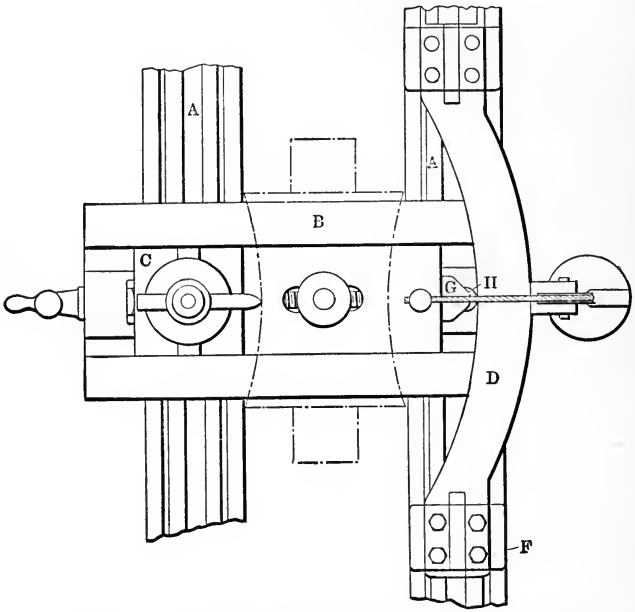


Fig. 157. — Plan of Attachment for Turning Convex and Concave Rolls.

tion roll H brought against the curved guide-bar D by the weight K, and the finishing cuts taken to the proper curve.

When the rolls are to be made largest in the center, the guide-bar D is reversed, bringing its convex side next to the friction roller H.

A similar attachment, or in fact this one, may be used to finish other curves, whether simple or compound, so long as the contour is made up of easy curves capable of being followed by the friction roller H, as shown in the engraving. Small pieces, say less than

six inches in length, may be more economically finished by means of forming tools.

Another very desirable attachment for machining concave and convex surfaces is of German origin. Figure 158 shows a front elevation and Fig. 159 a plan of a lathe fitted with this attachment.

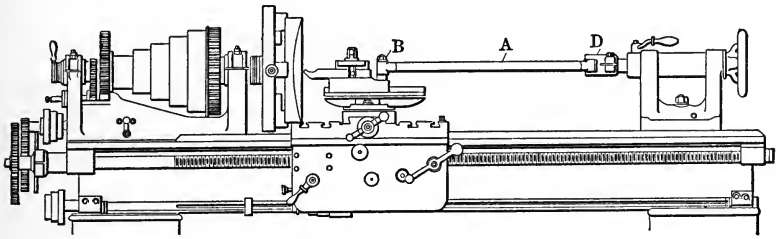


Fig. 158. — Front Elevation of Attachment for Turning Concave Surfaces.

It is very simple in its construction and consists of a radius bar A, which is pivoted at its rear end to a block D, and at its front end to the tool block of the compound rest at B. By reference to the plan in Fig. 159, it will be readily seen that as the cross-feed is operated, the compound rest must swing upon its center according to the radius of the bar A, and be governed by it.

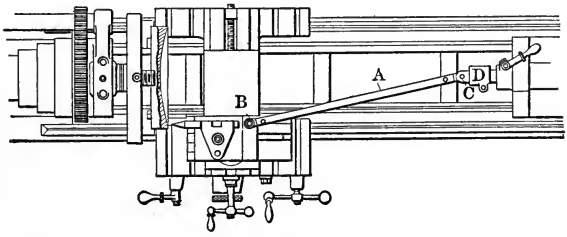


Fig. 159. — Plan of Attachment for Turning Concave Surfaces.

It is necessary for its practical working that all fits and adjustments must be nicely made and accurately set in order to have this attachment operative. Also, that unless the parts are all comparatively heavy and rigid, the cuts made would of necessity be light ones, otherwise the tool would be likely to have considerable vibration and leave "chatter marks" in the work.

It should also be remembered that for a large radius the tool

must project out farther from the center of the compound rest as in other attachments of the kind, since the radius bar has nothing to do with determining or governing the radius of the curve machined.

Figure 160 is a front elevation and Fig. 161 a plan of a similar

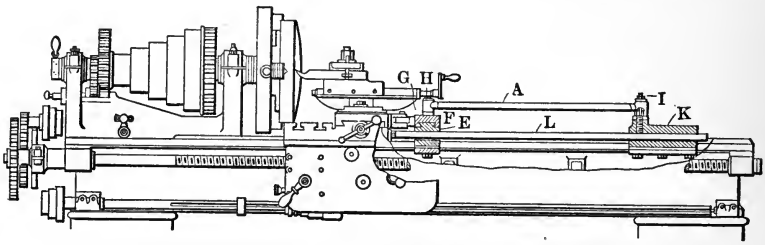


FIG. 160. — Front Elevation of Attachment for Turning Convex Surfaces.

attachment to the above, and of like origin, having for its object the machining of convex surfaces. This is a more complex matter, and the manner in which it is accomplished is at once ingenious and practical, and, so far as the author is aware, is new in this country.

In the design of an attachment so arranged as to effect the proper movement of the tool to produce a convex curve, that is, a drawing back of the cutting-tool as it advances, it is obvious that the length of the radius bar must be the same as the radius of the curve which it is to produce. The bar A is made to this length and

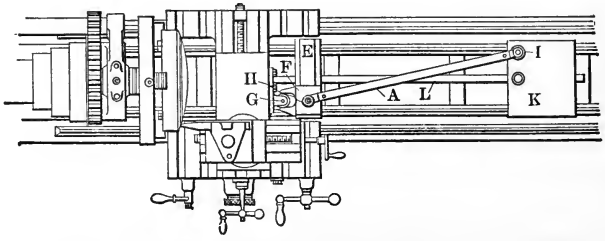


FIG. 161. — Plan of Attachment for Turning Convex Surfaces.

is pivoted at I to a slide K, free to move longitudinally on the lathe bed. The other end of the bar A is pivoted to a cross-slide F, which moves on a guide E, rigidly secured to the lathe bed. The carriage cross-slide has attached to it the roller G, which engages jaws in the slide F, and hence, as it is fed across the surface of the

work, the slide F is carried along with the carriage cross-slide. The resultant effect of the movement of the bar A is to move the block K along the lathe bed, and this movement is transmitted to the carriage by means of the connecting bar L, this compound movement causing the point of the tool to describe an arc of which the length of the bar A is the radius.

In this device, also, it is necessary to have all the parts strong and rigid, with bars, studs, bolts, etc., much larger and of better mechanical construction than those shown in the engraving, in order to insure accurate and well finished work as well that which will be economical in point of the time required to perform it.

In making cutters for use in milling machines, gear cutters and the like, it is not sufficient that the correct form be given to the face or cutting edge of the teeth only. This form must be carried on to the back of the teeth so that in grinding the face of the teeth, when they have become dulled from use, they will still maintain their original and correct form.

This would be a simple matter and might be readily accomplished in forming up the blank in the lathe previous to cutting the teeth, if it were not for the fact that there must be some "side clearance" allowed to the teeth. In other words, the teeth must be widest and the diameter of the cutter the largest across the cutting edge and the points of the teeth respectively, and the "form" carried back from this in a decreasing radius.

This form is produced by the process known by the technical term of "backing off."

There are various attachments in the market for performing this operation. The conditions of the case require that for each tooth of the cutter the forming tool must commence to cut at the cutting edge of the cutter, quickly move in toward the center until the cutting edge of the next tooth approaches, then fly back to the original position ready for cutting the next tooth. This motion is repeated for each tooth, and the tool-holding device must be likewise capable of being constantly adjusted to the depth of the cut as the metal is cut away so as to reduce it until the cut comes quite near the cutting edge.

From these conditions it will be seen that there must be a quick advance and an instantaneous return of the forming tool for each

tooth of the cutter. To produce this movement is the function of the "backing-off" or "relieving" attachment.

An ingenious device of this kind is illustrated in Figs. 162, 163, and 164, of which Fig. 162 is a plan of the attachment, Fig. 163

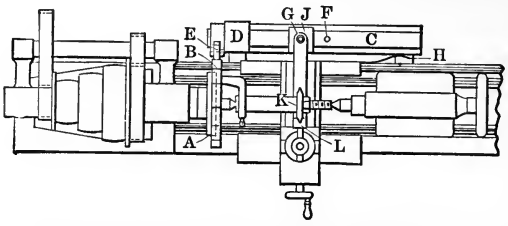


Fig. 162. — Attachment for "Backing-off" or "Relieving" the Teeth of Cutters.

shows one of the actuating cams, and Fig. 164 shows the bracket and friction roller that rests against the actuating cam shown in Fig. 163.

The construction of the device is as follows: Upon the small face-plate A of the lathe is fixed the actuating cam B, shown in Fig. 163. Upon the swivel bar of a regular taper attachment C is fixed the bracket D, in the upper end of which is journaled the friction

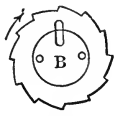


Fig. 163. — Ratchet Cam for "Backing-off" Attachment.

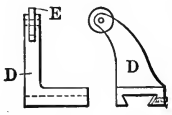


Fig. 164. — Bracket for Cam Roller of "Backing-off" Attachment.

roller E, which bears against the actuating cam B. The swivel bar is pivoted at F, as usual, and when used for the purposes of this attachment the clamping screws at either end (not shown) are left slightly loose so as to permit it to swivel slightly, and the friction roller E held tightly against the actuating cam B by means of a strong spring at H. K is the cutter to be "backed off," and L is the forming tool doing the work.

The compound rest, or cross-slide, as the case may be, is connected to the taper attachment sliding block J by a pivot bolt G, in the usual manner.

The operation of the device is this. The swivel bar of the taper attachment forms a lever by which the motion derived from the actuating cam B is conveyed to the tool-holding device of the compound rest, the forming tool being drawn in as the friction roll E rides up on the cam tooth, and suddenly dropping back to its original position as the roller drops off the point of the cam tooth, the actuating cam always revolving in the direction indicated by the arrow.

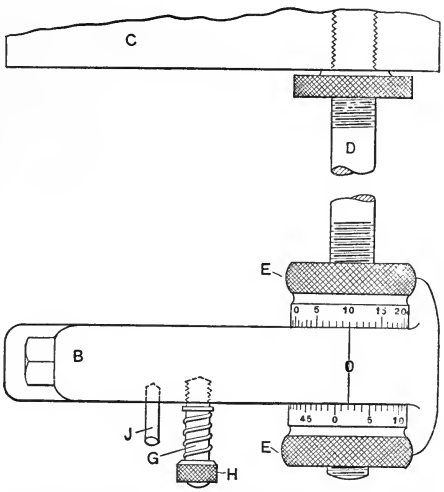


Fig. 165. — Plan of Micrometer Stop Attachment for Cross-Feed of Lathes.

There are two important advantages possessed by this arrangement. First, it is very economically and conveniently applied to an engine lathe having a taper attachment. Second, as the taper attachment swivel bar is used as a lever in obtaining the motion desired, this leverage may be as small or as great as desired by bringing the pivot bolts F and G nearer together or farther apart. Thus the amount of "clearance" given to the teeth of the cutter is entirely under the control of the operator, who can change or modify this condition at any time, even while the work is in progress, by simply moving the taper-attachment brackets to the right or left on the lathe bed.

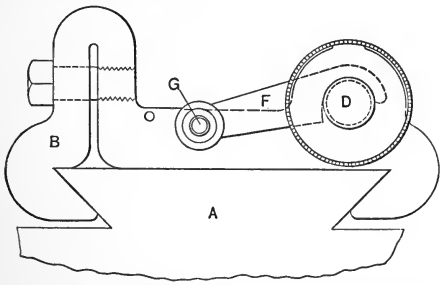


Fig. 166. — Front Elevation of Micrometer Stop Attachment for Cross-Feed of Lathes.

In Fig. 165 is shown the plan, and in Fig. 166 the elevation, of a convenient and practical stop for the cross-feed of an engine lathe. It is not only very useful in thread cutting but in getting

accurate dimensions of both inside and outside work, as well as to accurately turn different diameters with the same tool and at the same setting.

The construction of the device is as follows: Upon the cross-slide A is fitted the cross-feed stop B, constructed as usual. Through this piece and into the tool block C passes the stop stud D, being fixed in the latter piece. This stud is threaded 20 to the inch, and the micrometer nuts E, E, graduated in 50 spaces, thus giving a reading of .001, upon which quarter thousands may be easily determined.

The micrometer nuts are recessed on the side next to the feed stop B, and provided with a washer and short spiral spring. The washer is prevented from turning except with the nut by a small pin in the nut and fitting in a suitable notch in the edge of the washer. This washer is threaded the same as the nut E, and the action of the spring causes friction enough on the thread to prevent the nut from turning by any jar to which the lathe may be subjected. This construction also excludes dirt and takes up wear when the device has been in use for any great length of time.

Two micrometer nuts are used so that inside as well as outside work may be accurately turned.

When different diameters are to be turned, stop levers of varying thickness, one of which is shown at F, are used by placing them on the stud G, and secured by the nut H and its spiral spring. This stop must, of course, be exactly one half the difference between the large and the small diameter in thickness. In use it is turned down so as to come between the stop B and the micrometer nut E. When not in use it is turned over against the pin J. Two or more of these stops may be used without removing either of them, provided the one next to the stop B is used first and the others added successively to it, or vice versa.

While such an attachment as the one here shown is a valuable aid to a careful operator, it is not an assurance that accurate diameters will be continuously turned out when the operator becomes careless and "runs hard against the stop," or is guilty of the opposite error of not coming closely up to it. Both these errors have caused a great deal of trouble to shop foremen.

In these modern days and days of modern methods, when me-

chanical accuracy is the great desideratum, the subject of grinding cylindrical surfaces has absorbed a great deal of attention. It was long ago realized that it was next to impossible to construct a lathe so accurate that it was possible to turn a perfectly cylindrical piece of work upon it.

Grinding was formerly used principally in the construction of gages of various forms, but particularly cylindrical gages. As grinding machines were simplified and improved it was found that the grinding processes were continually becoming more economical, and that therefore the extreme accuracy which such processes made possible could be applied to many other kinds or classes of work.

Grinding as performed in an engine lathe was accomplished by a "home-made" grinding attachment, more or less crude, and bolted down to the lathe carriage, tool block, or compound rest. The spindle carried a grooved pulley from which a round leather belt went up to a wooden drum hung up over the lathe and driven by a short belt from the lathe countershaft. This drum was as long as any grinding job was expected to be, since the round belt must needs travel to and fro upon it as the lathe carriage carried the grinding attachments over the length of the piece of work to be ground.

It must be admitted that even with these crude devices much good work was accomplished, and that the way was thus opened for the much better work that followed later on.

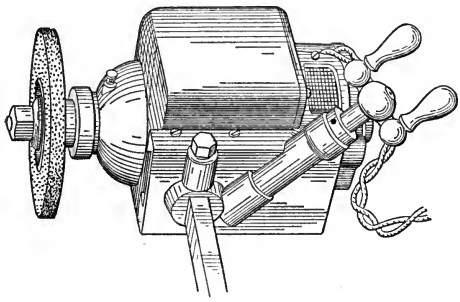


Fig. 167. — Tool-Post Grinding Attachment, made by Cincinnati Electric Tool Company.

With the introduction of electrical power and the ease with which small and compact motors could be constructed, the convenience of driving grinding devices was much increased and the old overhead wooden drum is fast becoming a thing of the past.

In Fig. 167 is given a view of one of the electrically driven lathe grinder attachments made by the Cincinnati Electrical Tool Company. It may be held in the tool-post or tool-clamping device, and

is entirely self-contained, the emery wheel being attached to the shaft of the small electric motor within the metallic case. It is driven by the current coming through an ordinary incandescent lamp cord. Its movements are regulated by the crank seen in front of the case, as well as by the cross and lateral feeding mechanism of the lathe.

Its compact form, portability, and the convenience of attaching, using, and detaching, render it a very useful lathe grinder. It can be set at any angle so as to grind taper work as well as straight, and the centers of the lathe in which it is used.

Figure 168 is of a center-grinding attachment made by the

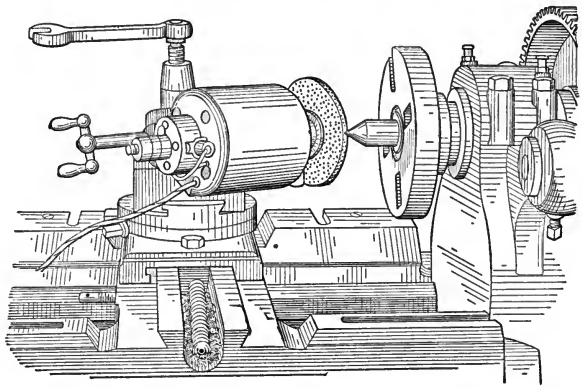


FIG. 168. — Lathe Center Grinding Attachment, made by the Hisey-Wolf Machine Company.

Hisey-Wolf Machine Company, and is shown attached to a lathe in the proper position for grinding the head-stock center. Like the last example it consists of an electric motor whose shaft carries the emery wheel. The shaft is arranged to travel endwise as is necessary in center grinding, and is operated by means of the double crank shown at the left. It is driven by the current from an ordinary lamp cord.

Figure 169 represents a larger grinding attachment made by the same company and designed for larger and heavier work than either of the above devices. It is arranged to be bolted down upon the lathe carriage, or a block attached to it so as to bring its center at the same height as that of the center line of the lathe. It is driven in the same manner as the last two devices.

The entire motor and case is attached to a square block having a vertically sliding surface planed upon it, and fitting the bolting-down and supporting bracket upon which it slides vertically, being adjusted as to height and held in any desired position by the double crank seen at the top.

By extending the shafts of these motors, either temporarily or by having them so constructed when built, to the proper distance so as to carry the emery wheel at a considerable distance from the motor, they may be used for grinding the inside of cylindrical work, the longitudinal feed of the lathe being made use of to give the required travel for the wheel.

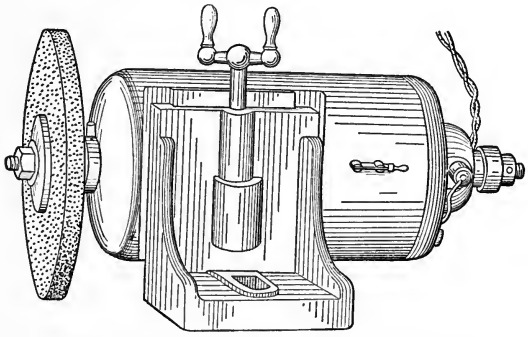


FIG. 169. — A Larger Lathe Grinding Attachment, made by the Hisey-Wolf Machine Company.

Should the inside work be conical it is entirely practical to attach the grinder to the compound rest, set at the proper angle and the wheel fed back and forth quite as readily as on straight work.

Being electrically driven the device may be set with its shaft at right angles to the center line of the lathe, and face grinding may be conveniently performed.

In fact there are hardly any of the ordinary grinding operations that are required to be done on centers that may not be performed by one of these grinders, even to cutters, reamers, and the like, by a little ingenuity in arranging for them.

These points make such grinders of a great deal of value in ordinary machine shops and manufactories, and almost indispensable in the smaller shops where it is not always possible to get a regular grinding machine.

The Rivett-Dock thread-cutting attachment, shown in Fig. 170, may with propriety be classed as a *tool*, but from its importance in design, use, and effect it seems to deserve being classed as an *attachment* and so it is made a part of this chapter.

Its construction and operation is as follows: The angle plate A is adapted to be bolted down on the tool block of the lathe, and upon its upright face is fitted the horizontal slide B, which may be moved forward and back by means of the lever C. The slide B has pivoted to it the circular cutter D, whose ten teeth are shaped in the

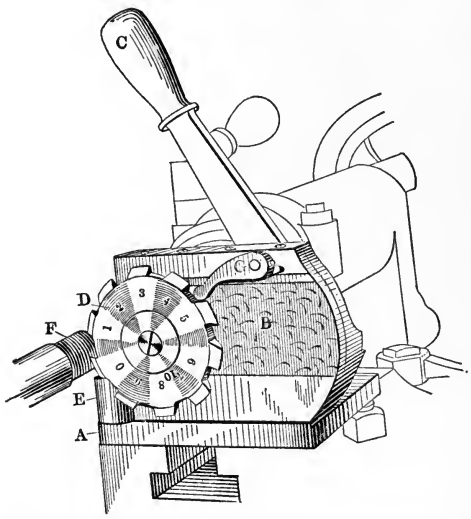


FIG. 170. — The Rivett-Dock Thread Cutting Attachment.

form of the thread. However, the *full* form of the thread is only given by the last one used in cutting the thread, the others being gradually cut away so that the first one hardly more than marks the location of the cut, the design being to cut the full thread at ten cuts, each successive tooth of the cutter cutting a little deeper until the tenth tooth shall have but a trifle to cut to finish the thread.

It will be noticed that the tooth marked O in the engraving rests upon a projection E, which supports it in its cutting position to act upon the piece F which is being cut. The cutter having made one cut is withdrawn from contact with the work by the

handle C, by which motion the pawl G, pivoted at the top of the angle plate A, engages in the space between the teeth of the cutter D, and causes it to rotate to the left just far enough to bring the next tooth into the cutting position. The withdrawal of the cutter from the support E permits its revolution. The cutter is then thrown forward and the next tooth is ready for the cut. This operation is repeated until all the teeth have been brought into the cutting position and made their cut in succession, and the thread is completed.

The important point accomplished by this device is that as there should be ten cuts made to complete a thread, the keen edge of the tool for finishing is liable to be lost in the earlier roughing cuts. With this device the roughing cuts are made with teeth designed for that work particularly, and the thread is brought to a state of completion by what is practically ten different tools. Hence a saving of time, both in cutting and in grinding tools, and the production of a smooth, accurately finished, and perfect thread.

CHAPTER X

RAPID CHANGE GEAR MECHANISMS

What a rapid change gear device is. The old pin wheel and lantern pinion device. The first patent for a rapid change gear device. The inventors' claims. Classification of rapid change gear devices. The inventors of rapid change gear devices. Paulson's originality. "Change gear devices" by the author. Le Blond's quick change gear device. The Springfield rapid change gear attachment. Criticism of the device. The Bradford rapid change gear device. Judd's quick change gear device. Newton's quick change gear device. The Flather quick change gear device.

By the term "rapid change gear" we understand that the mechanism so denominated is one capable of performing all the functions of the former change-gears but without the necessity for exchanging one gear for another or one set of gears for another, that is, without removing a gear.

These gears were formerly called "change-gears" because they were subject to *change* for each new operation of the lathe in which their use was essential.

In the old-fashioned "chain lathe," having a lead screw driven by "pin wheels" and "lantern pinions," which is illustrated and described in Chapter II, it will be seen that the builder had provided for changing the pitch of the thread to be cut by changing only one gear. This was about the year 1830. In 1882, George A. Gray, Jr., obtained a patent, No. 252,760, for a change gear arrangement whose principal feature was that only one gear need be removed and changed to cut any of the usual threads.

The first effort in the direction of devising a rapid change gear mechanism was, so far as the United States Patent Office is concerned, made by Edward Bancroft and William Sellers, who on February 7, 1854, obtained Patent No. 10,491, for a device con-

sisting of two cones of gears intermeshing, one set fast to the shaft and the other set adapted to fix any single gear to the shaft by means of a pin passing through a fixed flange and into a hole in a gear or the hub of a gear; the set being made with telescoping hubs, the ends of all coming against the fixed plate. It is interesting, in the light of present developments in this line, to read the first claim of their patent, so prophetic of the developments to come, as follows: "The method of varying the motions of the mandrel or screw-shaft, or leader, by means of two series of wheels of different diameters, and all of the wheels of one series being connected and turning together, and imparting motion to all the wheels of the second series with different degrees of velocity, substantially as described."

While a number of the later inventors claimed these same features of the mechanism and apparently considered themselves as the original inventors, it will be readily seen that the mechanical ideas involved in this invention anticipated their claims by a goodly number of years.

In considering the question of rapid change gear devices it will be well to adopt some classification based upon their design or structural differences. We may then illustrate and describe these general classes by well-known or readily understood examples, whereby all devices of this kind may be more easily understood and their special features appreciated at their proper value.

Thus we may classify these devices in their general groups as follows:

First, those in which the gears representing the former change-gears are all placed on one shaft;

Second, those in which these gears were placed on several shafts or studs, and arranged in a circle; and

Third, those in which neither of these arrangements existed.

Of the first class, using what has become well known as the "cone of gears," the most notable inventors are Bancroft and Sellers, Humphreys, Miles, Riley, Hyde, Joseph Flather, Peter and William Shellenback, Norton, William Shellenback, Herbert L. Flather, Ernest J Flather, Wheeler, Isler, Le Blond, Johnson and Wood.

Of this number it was usual to use one or two cones of gears,

but this number did not seem to satisfy the ambition of some of the inventors, since one of them, Isler, used no less than six cones of gears. Usually these cones of gears were located under the head or in front of it, but sometimes within the bed. But Johnson, apparently being determined to have a cone of gears *somewhere*, places them on a loose sleeve running on the main spindle. It remained for Wheeler to find a new location for his cone of gears by placing them in the apron.

Among all these devices, as in other spheres of mechanical effort, the inventors produced mechanisms ranging all the way from "good and bad, to indifferent."

Of the second class, that is, those who located the gears on short shafts arranged in a circle, the first to devise this arrangement was Edward Flather, who obtained patent No. 536,615, on April 2, 1895, and was later followed by Benj. F. Burdick, William L. Shellenback, Edward A. Muller, and Herman R. Isler, in the order named, the latter's last patent having been granted in 1902.

Of the exceptional examples, included in class third, the most notable one is the invention of Carl J. Paulson, who adopted the very original method of making a series of rings fitting inside each other, cutting gear teeth on a portion of the face of each and arranging the proper mechanism to thrust out from its fellows, the gear having the desired number of teeth that might be needed. This was probably the most original of all the methods employed up to the present time.

While this device was not a commercial success, it had a counterpart and was the prototype of a quite similar arrangement consisting of two sets of sleeves in line with each other and having teeth cut on their outer surfaces precisely as Paulson had done, and arranging them and their connecting gears in a more practical and operative combination.

An interesting review might be written and illustrated of the various patented change gear mechanisms that have been invented since the days of Bancroft and Sellers, but it is hardly within the scope of this work to give the necessary space to this portion of lathe description. If the reader desires to pursue the subject in detail and to have dates, patent numbers, and illustrations from the drawings in the patent office, he is referred to a book by the author

entitled "Change Gear Devices," wherein all this data is presented in detail.

For the purposes of this work it will be sufficient to present a few of the more recent examples in this chapter and to call attention to the engravings of a number of others in other chapters wherein the lathes of prominent builders are illustrated and the change gear devices shown. Among these are the lathes built by Hamilton Machine Tool Company, Bradford Machine Tool Company, Hendey Machine Tool Company, Prentice Brothers Company, Springfield Machine Company, etc.

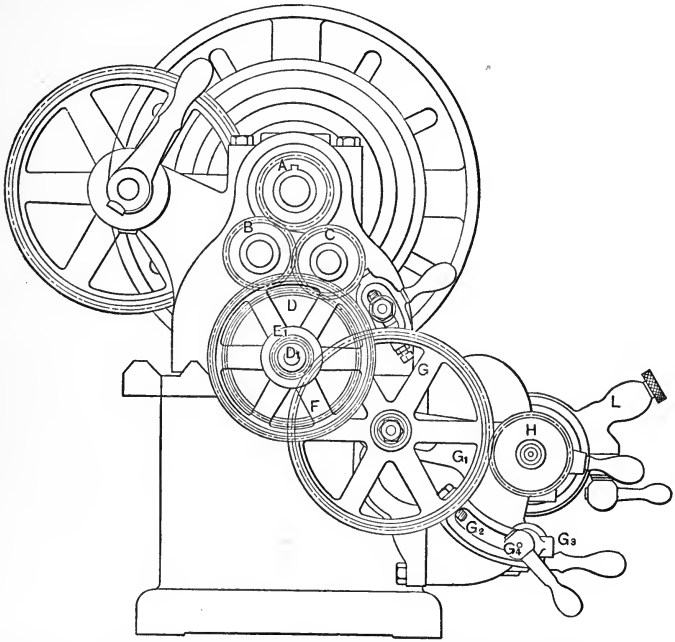


FIG. 171. — End Elevation of Le Blond's Quick Change Gear Device.

The quick change gear device designed by R. K. Le Blond is an interesting example of this type of mechanism. Figure 171 shows an end elevation of this lathe, and Figs. 172, 173, and 174 some of the details of the gearing.

The lathe, with the exception of these features, is the same as the standard engine lathe built by this company, and the headstock end is shown in Fig. 171, which gives a good idea of the exterior appearance of the change gear device.

The line drawing, Fig. 172, shows the connection between the feed box and the lathe spindle. The spindle gear A drives gear D on the stud D_1, through tumbler gears B and C. The tumbler gears are of the regular construction used for reversing the motion of the carriage in screw cutting, so as to cut either right or left hand threads, as required.

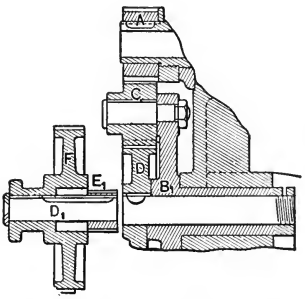


FIG. 172. — Sectional View of Le Blond's Quick Change Gear Device.

Motion is transmitted from the tumbler gears through gears D, E_1, G, and H, which latter is on the driving-shaft of the feed box. In order, however, to obtain a second series of feeds there is a telescopic slip gear located on the stud D_1 which can be made to mesh with gear G in place of pinion E_1 which is shown in mesh with gear G in the engraving. To accomplish this, G rotates on a pin in a quadrant G_1, which, by means of the clamping handle G_4 and the stops G_2 and G_3 can be brought into the correct position for gear G to mesh either with pinion E_1 or gear F, as required. The hub of gear F is recessed so that it can be slid over pinion E_1, thus bringing this gear in the same plane with gear G. Gears D and F and the pinion E_1 all rotate with the stud, which is journaled in a bearing in the head-stock casting. The introduction of the telescopic gear F makes a change in the feed ratio of 4 to 1.

Figure 173 is reproduced from the patent specification and shows clearly the mechanism of the feed box. A is the driving shaft and B the driven shaft, which in this case is represented as being one end of the lead screw, but in the actual lathe is connected with the latter by suitable intermediate gearing. However, the principle of the feed changes is the same in either case. Shaft B carries a cone of gears and shaft A an elongated spur gear C, which is the driving gear of the mechanism.

Surrounding this elongated gear C is a cylindrical barrel D, which serves the double purpose of a casing for the gear and a bearing for a sliding bushing E, by means of which the adjustment of feed is effected. This bushing carries at F an intermediate gear which at all times is in mesh with gear C and can also be brought

into mesh with one of the gears in the cone by giving the bushing E a combined sliding and rotary motion on the barrel D.

The portion of the barrel D which is toward the cone of gears is provided with a longitudinal slot, to allow the intermediate gear F to project through and mesh with gear C. The front portion of the barrel is provided with a series of holes, corresponding in number and position to the gears of the cone, so that the bushing which

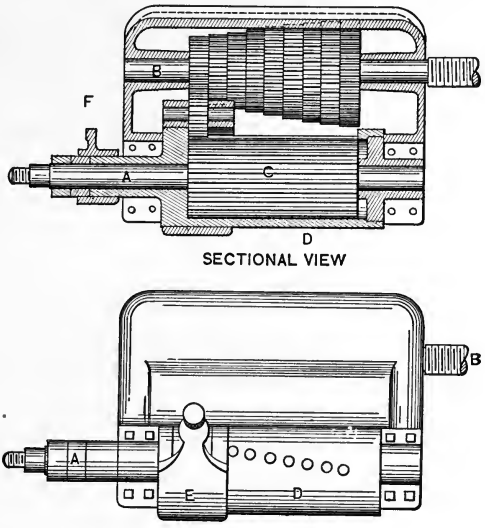


FIG. 173. — Details of Le Blond's Quick Change Gear Device.

carries the intermediate gear F can be locked in its proper position for each gear by means of a spring pin, after the usual manner. The bushing which acts as carrier for the gear, and the barrel which encases the elongated gear, are clearly represented in the detailed view of the mechanism, Fig. 173.

Figure 174 is a view looking at rear of the mechanism and its casing, and shows the modifications that have been made in the device to adapt it to the engine lathe. The cone shaft carries besides the eight gears of the cone, an additional gear, K, and below this shaft, which is marked B, is the shaft L, which is connected directly to the feed rod R, and carries a sliding sleeve S, on which are two pinions, M and N.

In the position shown in this view power is transmitted from the cone shaft B to the gear N by means of the auxiliary pinion K, and as the sleeve S is splined to shaft L the motion is transmitted to this shaft and thence to the feed rod. By sliding the sleeve to the right, gear N no longer meshes with pinion K, but instead pinion M meshes with one of the gears of the cone, causing the feed rod to rotate at a faster speed. The lead screw T is driven from the feed rod by a slip gear W, in the usual manner.

From the above description it will be seen that with the gear box itself eight changes of feed are obtained. The slip gear on the auxiliary shaft in the feed box makes 16 changes, and these 16 changes are again doubled by the telescopic gear on stud D_1, in

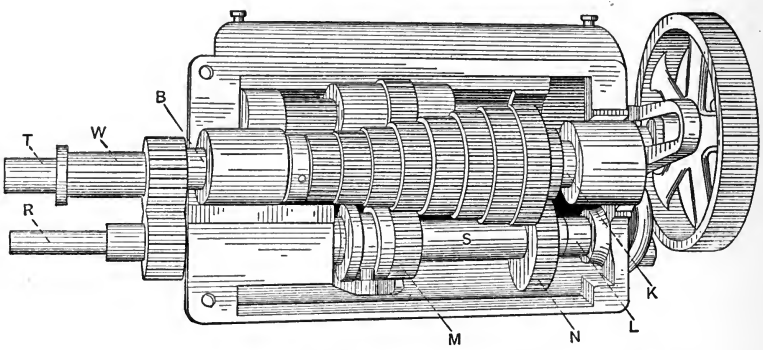


FIG. 174 —. Rear View of Le Blond's Quick Change Gear Device.

Fig. 2, making 32 changes and giving a range of threads from 3 to 46 per inch, covering every standard thread, including $11\frac{1}{2}$.

This entire range of threads can be made without stopping the lathe or removing a single gear. The feeds are four times the number of threads per inch. It will be noticed that the compounding generally adopted on this style of lathe is done away with, and that wherever there are coarse feeds or heavy threads the increase comes directly from the 4 to 1 gear on the stud D_1, speeding up the feed mechanism of the feed box in the same proportion, so that it is placed under no additional strain.

Figures 175 and 176 illustrate the "rapid change gear attachment" of the Springfield Machine Tool Company's "Ideal" lathe. They make use of the design placed in the second class,

that is, those which have their change-gears mounted upon studs or short shafts arranged in a circle.

The change-gears are mounted in a gear box, shown at the left-hand side of the engraving, Fig. 175, the intermediate and head-stock spindle gears being those ordinarily used. The cover of the gear box is rotated about a central stud, and the gears are carried

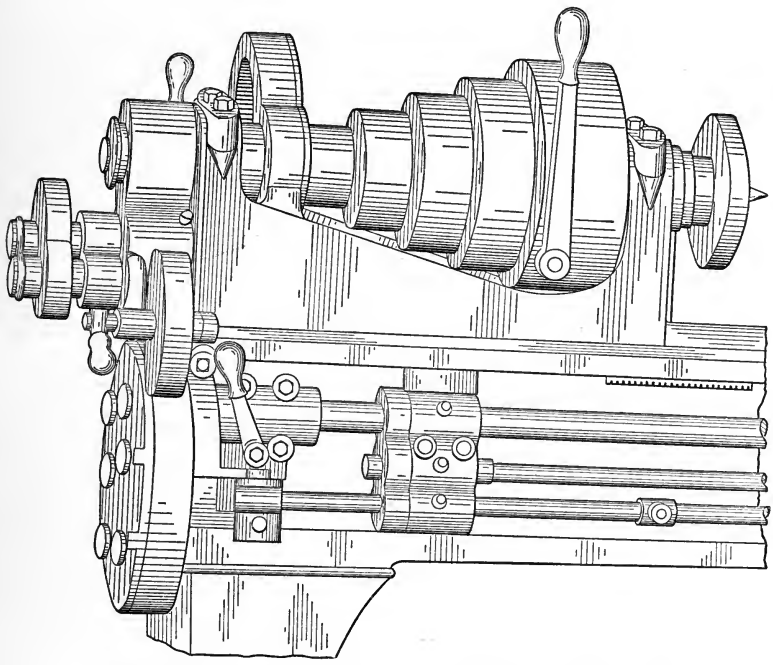


FIG. 175. — Rapid Change Gear Attachment built by the Springfield Machine Tool Company.

on the inside of the cover, arranged in a circle concentric with the case, and this circle brings the change-gears opposite the end of the lead screw by revolving the cover of the case.

Referring to Fig. 176, the small clutch C moves a telescopic extension of the lead screw and enters it into a hole in the change-gear before the driving clutches between the change-gear and the extension come into contact. This device takes the bearing of the change-gear upon the extension for its support, and secures the change-gear to the lead screw as firmly as if fastened by a nut. In order to change the gear, the cover is revolved until the desired

gear is opposite the center of the lead screw extension, when the small clutch is thrown. All of the eight change-gears are protected by the case except the top of the one which is in mesh with the intermediate gear.

To give a sufficient range of pitches, a set of three pairs of gears is provided in the head-stock to vary the speed of the intermediate

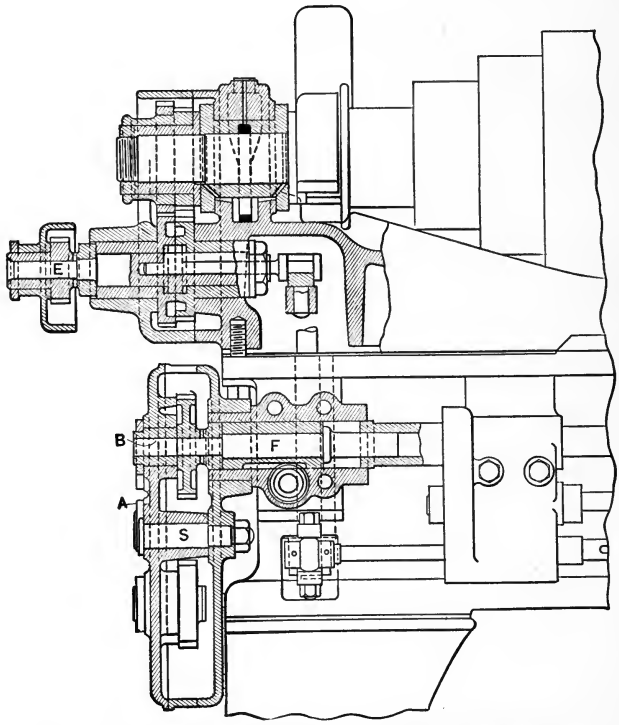


Fig. 176. — Longitudinal Section of Rapid Change Gear Attachment built by the Springfield Machine Tool Company.

gear. These are housed in the gear cases shown at the extreme end of the head-stock. These are clutched to their spindles by slipping them on until their clutches engage the spindles, which have clutches with their end sections reduced, as in the case of the lead screw shown at F in the sectional drawing, Fig. 176. These gears furnish ratios of from 1 to 1, 2 to 1, and 4 to 1. The last two may be reversed and five speeds may be given to the fixed pinion driving the intermediate gear. The intermediate gear

revolves on a fixed stud on a quadrant to which the handle is attached, and is removed from contact by raising the quadrant.

This lathe has a range of threads from 2 to 56 per inch, and a range of turning feeds from 8 to 224 turns per inch, and all the changes for any of these feeds or threads may be made while the lathe is running.

The objection to this device is the inherent weakness of the mechanism when the gears are arranged upon short studs or shafts set around a circle. These cased-in gears must of necessity be

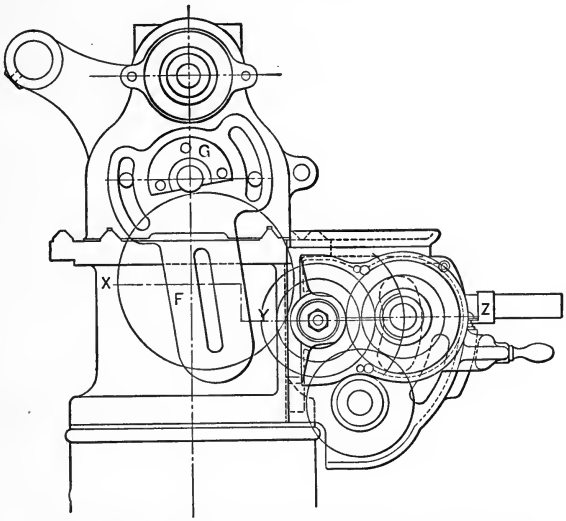


Fig. 177. — End Elevation of the Bradford Rapid Change Gear Device.

comparatively small and of narrow face. The teeth must, from the same conditions, be of fine pitch. Their support must be by comparatively small shafts. All these conditions render the mechanism structurally weak and less rigid than such a device should be to stand the strains of high-speed steel and modern cuts.

The Bradford Machine Tool Company build an ingenious rapid change gear device which is shown in the accompanying engravings, of which Fig. 177 is a front elevation, Fig. 178 an end elevation, and Figs. 179 and 180 are sectional views.

The method of transmitting motion from the head spindle to the change-gear mechanism will be readily understood by reference to

Figs. 178 and 179. This mechanism is contained in a gear box located in front of the bed, as seen in these two figures. It contains at A a cone of eight gears carried on a shaft for driving the feed rod and screw, and a sliding gear B, which acts as a driver for the cone and may be dropped into mesh with any one of the eight gears forming that member. The shaft-driving gear B carries loosely at the outer end three gears C, any one of which may be connected by a sliding key to the shaft. The three gears are rotated by gears

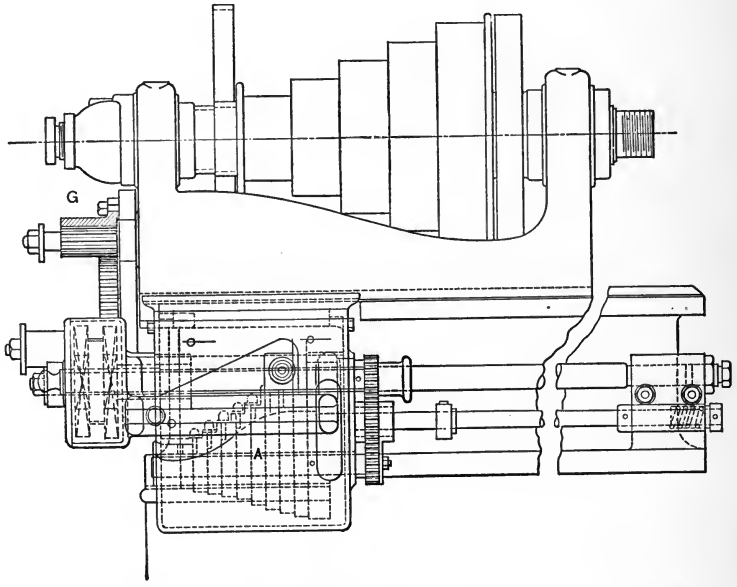


FIG. 178. — Front Elevation of the Bradford Rapid Change Gear Device.

mounted freely at D, the intermediate E carried on a long stud on quadrant F being engaged with one of the three in the set D.

Now, leaving the gears in the positions shown, it is obvious that by operating the plunger controlling the key in gears C, twenty-four rates of feed may be obtained, or eight for each gear in set C. Then, by the three positions for intermediate E, the number of feed change is increased to seventy-two.

At G will be noted a support for the driving gear which is formed solidly on its shaft. The bracket G is bolted to the quadrant and has the under part cut out to allow the intermediate gear to mesh

in the pinion, and as the bracket turns with the quadrant it supports the pinion no matter which one of the three gears the intermediate may be in mesh with.

Figure 180 shows the quick change gear cut entirely out, and ordinary change-gears used. It shows also on an enlarged scale the plunger and sliding key whereby one of the three gears C may be keyed to the shaft, allowing the other two to rotate loosely. The knurled knob can be taken off, allowing a gear of any required size to be put on the lead screw. The three gears are fitted with tool steel bushings, hardened and ground. The center gear has a keyway cut through, and each of the outside gears a keyway cut on one side only, allowing the knurled knob and plunger to be pulled in, out, or to central position. A spring pin holds the plunger when set.

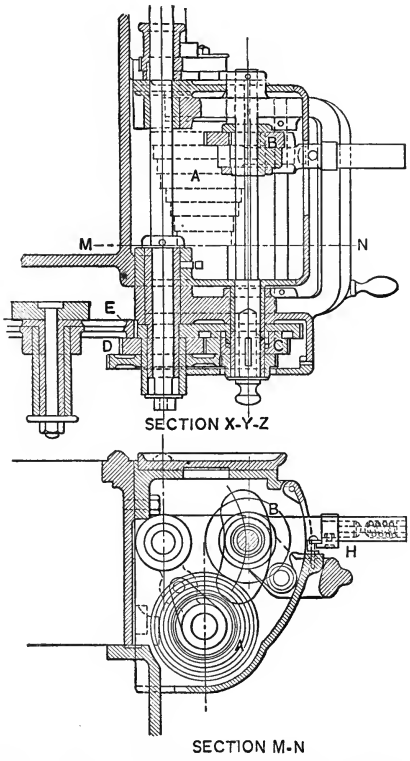


Fig. 179. — Sectional Views of Bradford Rapid Change Gear Device.

The locking device for the handle which controls the position of gear B is shown at H, Fig. 179, and consists of a shoe with a semicircular recess at the end which snaps under the heads of the locking screws, each screw head being of a conical form, as in the enlarged detail at P, Fig. 180, to fill a cavity in the under side of the controlling handle.

The screws can be raised and lowered to allow the gear in the frame to mesh correctly with the gears of the case, thereby enabling the operator to use gears other than those ordinarily used, simply by adjusting the screws until the gears mesh properly. The rela-

tive positions of the eight screws will be seen in the front view near A, Fig. 178

The threads cut with this gear range from 3 to 46 per inch, the screw-cutting feeds being $4\frac{1}{2}$ times the feeds for turning.

The quick change gear device shown in section in Fig. 182, and in front elevation in Fig. 181, is the invention of Joseph Judd, a draftsman employed by the New Haven Manufacturing Company.

It is unique in that in all other efforts at devising a quick change gear mechanism the shafts have been located parallel to each other.

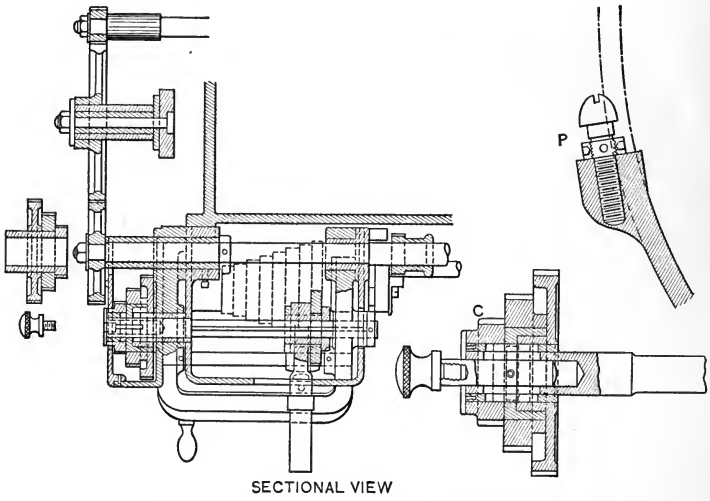


FIG. 180. — Sectional View of Bradford Rapid Change Gear Device.

After much study of the subject in conjunction with the author, and after all former devices known in the patent office had been thoroughly investigated and studied and their features carefully classified, after they had in fact all been *dissected,* as it were, the question of obtaining the most simple and direct acting device was sought by the process of elimination of the undesirable features of other devices, and Mr. Judd hit upon the idea of making the faces of the gears composing the "cone gears" slightly inclined instead of straight, and thus make it in reality what it had been before in name, a veritable *cone* of gears.

While this form is not theoretically correct the difference is

very slight when applied to a full-sized gear, and the device operates much more smoothly than many would suppose.

The device includes a cone of gears composed of seven members L, and mounted upon the lead screw shaft P, to which they are fixed. Above this cone of gears is a pinion B, with an equally inclined face, and mounted upon the quill G so that it can be moved longitudinally to permit of its being engaged with any one of the

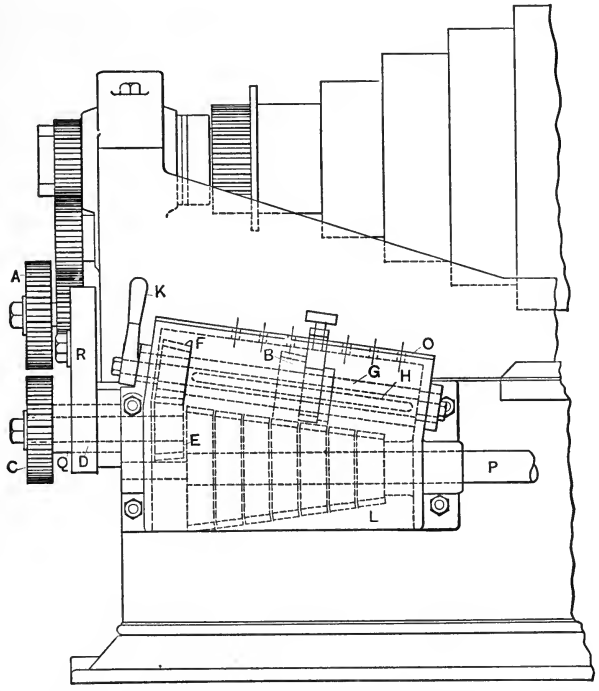


FIG. 181. — Front Elevation of Quick Change Gear Device, built by the New Haven Manufacturing Company.

seven gears below it. The quill or sleeve G is splined so that the pinion B may slide upon it, but must turn with it, in order to convey motion to the pinion B. The quill G is driven by the beveled pinion F keyed on the end. The pinion F, in turn, receives its motion from the beveled pinion E, which is mounted on the change-gear shaft D, and which carries at its outer end the change-gear C. The shaft H, supporting the quill G, is mounted

in two eccentrics J, J, which give the beveled pinion B an in-and-out motion relative to the nest of gears when manipulated by the handle K for changing the gear ratio.

The sliding pinion B is moved longitudinally to the position indicated by the index plate for the desired thread or feed, by means of the knob M, and after being engaged with the desired gear is held in position by the pin N. This pin enters a hole marked with the number of teeth of the gear with which the pinion is engaged, being, for instance, 48 in the engraving. This provides quick changes by steps between and including the ratio 32 to 56.

For wider ranges on the lathes of 32-inch swing and larger, a stud-plate R is mounted on the hub Q at the left end of the gear box O, carrying gears so arranged that threads from 2 to 14 may

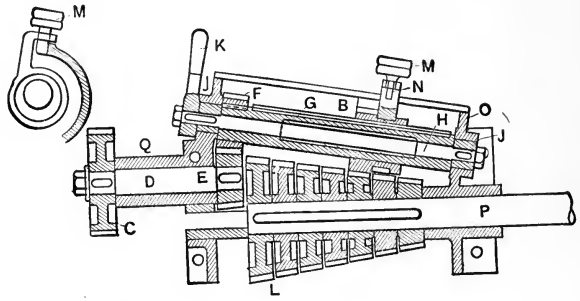


Fig. 182. — Longitudinal Section of New Haven Quick Change Gear Device.

be cut, or feeds from 8 to 56 obtained without changing the position of the intermediate stud, the gears being so porportioned that as one is removed from the change-gear shaft E, it is used as the intermediate gear, and so on.

Open washers are used on the ends of the studs so that no nuts have to be removed, thus making this portion of the change easily and quickly effected.

On lathes of 18 to 28-inch swing, inclusive, four additional changes are provided. This is effected by adjusting gear A longitudinally, permitting it to be meshed with either of the intermediate gears, the intermediate gear in this case being compound; and by mounting two gears at C on the change gear shaft.

These gears are of different diameters and both mesh with the

compound intermediate gear. A sliding spring key is provided by which either gear can be thrown into clutch with the shaft, thus giving the four changes without changing gears, the stud-plate having to be shifted on its pivot for two of the changes.

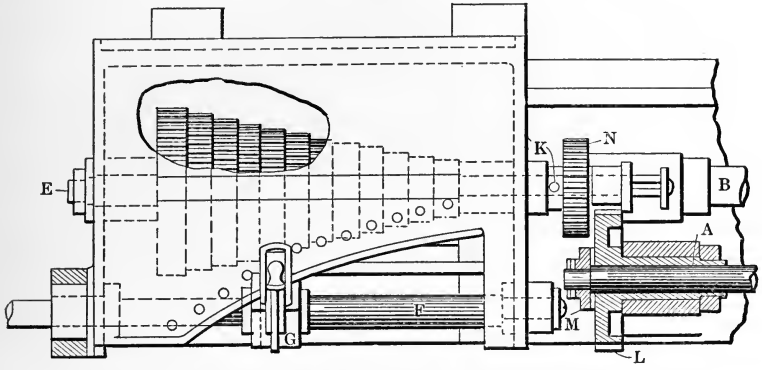


FIG. 183. — Front Elevation of Newton's Quick Change Gear Device.

This gives a range from 1 to 15 threads per inch and feeds from 4 to 60 per inch inclusive. By changing gear A, the other changes, of course, are readily obtained.

It will be noticed that the device is very compact and very simple, requiring a less number of gears and other operative parts than almost any device adapted to give a like number of useful changes.

Figure 183 is a front elevation and Fig. 184 a partial cross section of the quick change gear device invented by Albert E. Newton and applied to the lathes built by the Prentice Brothers Company.

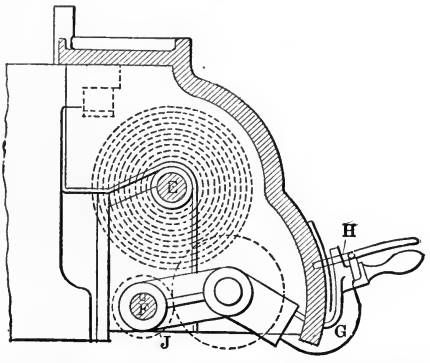


FIG. 184. — Partial Cross Section of Newton's Quick Change Gear Device.

The inventor has directed his efforts to the production of an improved change speed gearing of suitable form for economical manufacture and installation and which would be conveniently handled to actuate the feed rod or the lead screw.

The construction and operation of the device is as follows:

The lathe carriage may be actuated by the usual feed rod A or may be driven by the lead screw B when screw cutting. There is a bearing in the rear end of the head-stock for the shaft C and this is driven from the spindle through the usual tumbler gears arranged for the handy reversal of the shaft.

There are three gears fastened to the shaft C and there is a sweep D having a transverse slot fitting a bolt threaded into the end of the lathe bed. The sweep or stud-plate can be turned about its supporting hub and fixed in any position to which it is adjusted. By this means an intermediate gear can be put in mesh with any two of the six gears shown, and this forms a very convenient arrangement for a three-speed connection and avoids the use of an interchangeable set of gears at this point, the change being made with gears already in position for the purpose.

As will be noticed, the intermediate gear need be no greater in width than any of the six gears with which it meshes.

A countershaft E carries a series of gears. On the shaft F is a forked lever G, and between the arms of the latter is a pinion J with a key engaging the keyway cut in F. An intermediate gear in mesh with the pinion, is journaled on the stud extending between the parts of the forked lever G. The end of this lever is turned upward and is provided with a handle. A pin H is fitted in the ear extending from the lever and is controlled by a spring-pressed trigger carried by the handle.

A cover plate is secured to the bed to form a box over the change-gears, and the front lower edge of the plate, as illustrated in Fig. 183 has a guiding rib supporting the pin H. A series of holes is bored in the cover plate and in line with the gear-wheels. The forked lever G and the pinion J can be slid along the shaft F, and opposite the proper gear the handle may be lifted and locked in place by means of the pin H.

The end of the countershaft E projects through the right-hand journal and has a keyway cut in it. A slip pinion K is fitted on this projecting end and has a key engaging the keyway. A gear N is on the end of the lead screw B. The gear L has a hub fitted in the bearing supporting the left-hand end of the feed rod A. The gear

L is provided with clutch teeth to match teeth on a clutch M arranged at the end of the rod A.

A spring normally keeps the toothed parts in contact. An adjustable collar on the feed rod enables the carriage to be automatically stopped when a predetermined point in the travel is reached. The slip pinion K on the end of the countershaft E can be adjusted to engage either the gear N on the lead screw or the gear L that actuates the feed rod.

The step gearing on the countershaft E permits the same change speed gearing to drive the feed rod or the lead screw and that when

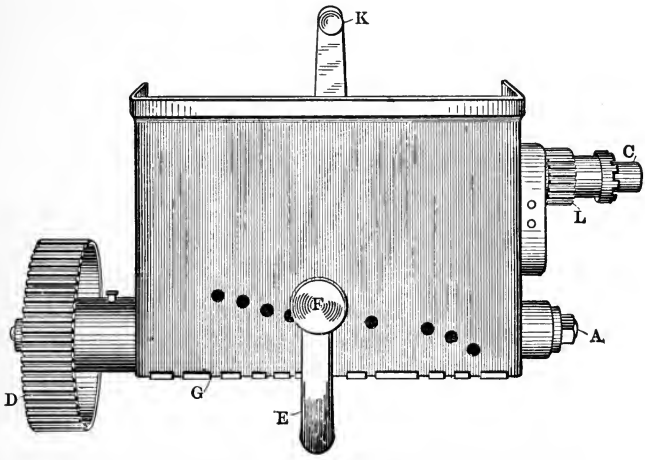


FIG. 185. — Front Elevation of Flather's Quick Change Gear Device.

either member is in use the other is idle. The arrangement of the countershaft E and the shaft F allows them and their gearing to be assembled on the bench.

The lead screw and the feed rod can be applied to the machine by bolting the brackets which support the lathe to the bed. Then the supporting bracket is put in position so that the triple gears will come in the same plane with their mates, and that the countershaft E will be in line for the engagement of the slip pinion K with either gears M or N.

Figure 185 gives a front elevation and Fig. 186 a rear elevation of the Flather quick change gear device, which is a simple and

practical device and apparently well adapted for the purpose, as most of their devices are and have been for many years.

From here the motion is transmitted by a train of gears, which will be described later, to the gear D, which drives shaft A in the feed box. This shaft is cut for a part of its length with teeth to form a long pinion, and on this portion slides the lever E. The shaft B carries the cone of gears usual in arrangements of this kind, and pivoted in the lever E, but not shown in any of these cuts, is the usual intermediate gear, which meshes with the teeth cut in the shaft A, and can be brought into mesh with any of the series of gears on the shaft B.

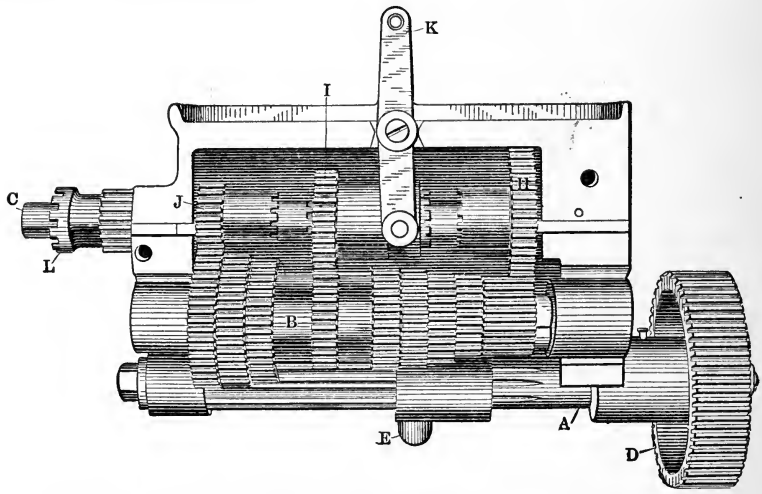


FIG. 186. — Rear Elevation of Flather's Quick Change Gear Device.

The locking pin F locates the lever in each of its different positions by entering into the appropriate hole drilled in the face of the gear box. G is a steel plate fastened to the lower edge of the box, and provided with a notch to match each locking pin hole. A projection on the inside of the lever E enters one of these notches, and prevents the lever from being shifted along the shaft until the intermediate gear has been dropped clear of the gears on the shaft B.

A new feature in this device is the fact that means are provided in the gear box for giving three different speeds to the feed rod or lead screw for each position of lever F. The shaft C has turning loosely upon it two gears, H and J, whose hubs are cut to the form

of clutch teeth. Between these two gears is a third one marked I, which has clutch teeth at both ends of its hub, and is splined to the shaft, but free to move endwise. An endwise movement is given to it through the lever K, which projects through the top of the box.

When in the position shown, the motion is evidently transmitted from shaft B to shaft C through the gear I, and its mating gear in the series on the shaft B. The gear I may be thrown either to the right or left, and thus be disengaged from its mate, but connected by the clutch teeth on its hub with either of the gears H or J. As these are run by their corresponding drivers at different rates of speed, each position of the lever E, by shifting lever K, will give three different speeds, or twenty-seven in all. This is the usual way of changing the turning feeds in the shop of the manufacturer; the lever E being located at a suitable station, the roughing and finishing feeds are obtained by the lever K.

The gear I has a spring pin in its hub which engages suitable depressions in shaft C, and thus prevents the lever K from being jarred out of position. The shaft C is extended through the gear box and carries a pinion and clutch L, which may be moved to the right to engage the clutch on the lead screw, or moved to the left to mesh with the gear on the feed-shaft.

The 27 feeds and threads mentioned are further increased to 54 by means of a sliding gear which meshes with the wide-faced gear D and is moved in or out by the projecting hub seen at M. Suitable gearing in the case N alters the ratio of rotation for these two positions. While this arrangement gives 54 feeds varying from 7 to 448 per inch, the threads from 2 to 128, the range is still further extended to permit the cutting of odd threads, metric pitches, etc., since the gear D may be removed and one of any suitable number of teeth inserted in its place.

CHAPTER XI

LATHE TOOLS, HIGH-SPEED STEEL, SPEEDS AND FEEDS, POWER FOR CUTTING-TOOLS, ETC.

Lathe tools in general. A set of regular tools. Tool angles. Materials and their characteristics. Their relation to the proper form of tools. Behavior of metals when being machined. The four requisites for a tool. The strength of the tool. The form of the tool. Degree of angles. Roughing and finishing tools. Spring tools. Tool-holders. Grinding tools for tool-holders. Dimensions of tools for tool-holders. The Armstrong tool-holders. Economy of the use of tool-holders. High-speed steel. A practical machinist's views on high-speed steel tools. Conditions of its use. Preparing the tool. Testing the tool. Speeds and feeds. Much difference of opinion. Grinding the tools. Amount of work accomplished by high-speed steel tools. Average speed for lathes of different swing. Speeds of high-speed steel drills. Mr. Walter Brown's observations on high-speed steel. Its brittleness. Its treatment. The secret of its successful treatment. Method of hardening and tempering. Method of packing. Making successful taps. Speeds for the use of high-speed steel tools. Economy in the use of high-speed steel tools. Old speeds for carbon steel tools. Modern speeds. Relative speeds and feeds. Modern feeds for different materials. Lubrication of tools. The kind of lubricant. Applying the lubricant. Lubricating oils. Soapy mixtures. Formula for lubricating compound. Improper lubricants. Various methods of applying lubricants. The gravity feed. Tank for lubricant. Pump for lubricant. Power for driving machine tools. Calculating the power of a driving-belt. Impracticability of constructing power tables. Collecting data relating to these subjects. Flather's "Dynamometers and the Transmission of Power." Pressure on the tool. Method of calculating it. Flather's formula. Manchester Technology data. Pressure on tools.

With comparatively slight exceptions the ordinary lathe tools are of the same form as those used in the time of the old chain lathe with a wooden bed. While the modern machinist has found some new shapes for special work and has been provided with all sorts and forms of tool-holders, and it is probable that many new and

perhaps improved forms will be brought out in the future, the same old forms will probably be used for a considerable part of lathe work as long as there is a lathe to use them on.

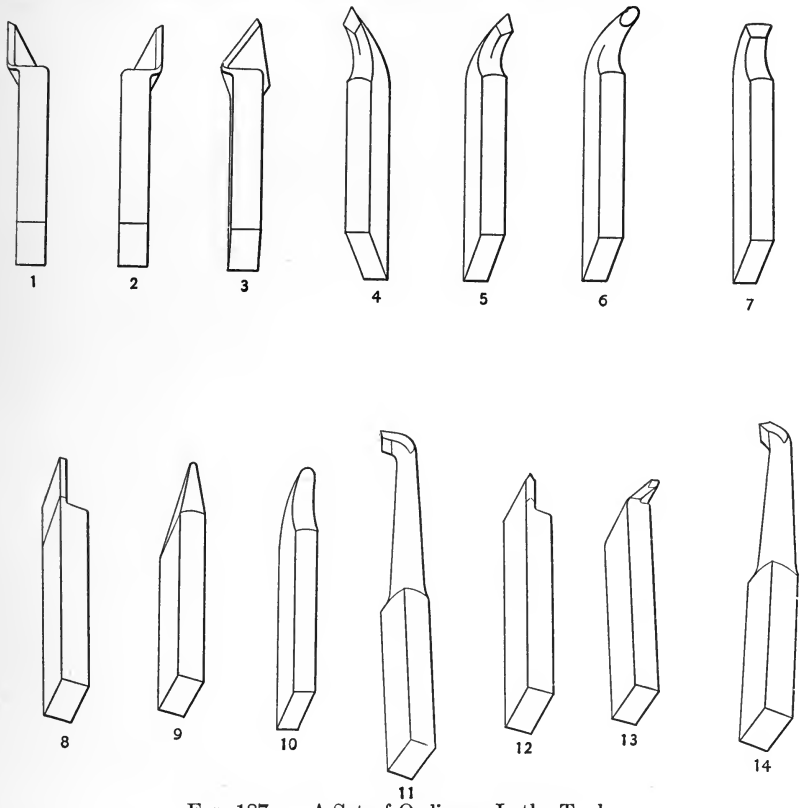


Fig. 187. — A Set of Ordinary Lathe Tools.

A set of fourteen of these time-honored tools is shown in Fig. 187, which are usually known by the following names, the numbers given in the engraving being referred to:

1. Right-hand Side Tool.
2. Left-hand Side Tool.
3. Right Bent Side Tool.
4. Right-hand Diamond Point.
5. Left-hand Diamond Point.
6. Round Nose Tool.
7. Cutting-down Tool.
8. Cutting-off Tool.
9. Narrow Round Nose Tool.
10. Wide Round Nose Tool.
11. Inside Boring Tool.
12. Straight Thread Tool.
13. Bent Thread Tool.
14. Inside Thread Tool.

In nearly all these tools their names indicate their uses, which is quite apparent also from their form.

The question of the proper angles to which lathe tools should be formed is an important one and there are a good many theories in relation to the subject. It is a matter of continual discussion among shop-men who are inclined to disagree very much on the subject. It is altogether probable that this disagreement is not so much that the question is one impossible of solution as it is that each man determines the question for himself from the standpoint of his own experience and with the range of material with which he has to work: otherwise, with the *conditions* which govern the work under his observation.

These conditions are so varied and so numerous that no fixed rules for forming tools to meet them all is possible. Some of them are these:

We have ordinarily to handle such materials as tool steel, machine steel, steel castings, wrought iron, cast iron, bronze, brass, copper, aluminum, babbitt metal, hard rubber, vulcanized fiber, rawhide, and a number of others constantly coming to hand. These substances as here mentioned give a very wide range to the kind and shape of the tools that it will be proper to use. But there are varying degrees and conditions in the same material that still further complicate the question.

Steel may be hard and brittle, or it may be soft and tough. It may be of any percentage of carbon up to and perhaps over one hundred points, and still we must make a tool to cut it.

Wrought iron may have somewhat similar properties as steel, but, of course, in a much less degree.

The alloys of copper commonly known as hard bronze, nickel bronze, gun metal, brass, yellow brass, and so on, through an almost endless variety of mixtures, will require almost as many different forms as must be used in turning the different grades of steel.

And so it is to a greater or less extent with all the different materials with which we have to deal.

In a general way we may say that the quality of the material we have to cut will influence the results in two ways: first, as to whether it is hard or soft, and second, whether it is crystalline or

fibrous. Its varying degrees of hardness or softness determine whether much or little can be removed in a given time; or, what amounts to the same thing, whether the speed of the cutting shall be fast or slow, and whether the feed shall be coarse or fine. Its crystalline or its fibrous nature will make considerable difference in the top angles of the tools, and this will be readily seen in the tendency of the crystalline metal to break up into small chips, while the fibrous turnings will curl off into spiral or helical shavings. Therefore the fibrous material will have the sharper angle than that designed for the crystalline structure of metal.

Of course all tools must be harder than the material they are to cut; at the same time they must not be so hard as to be brittle, or be made of a quality of steel that becomes brittle when hardened, but tough and strong and capable of maintaining their cutting-edge uninjured during their ordinary use. The fact that they do this will be best evidence of the correctness of their angles, provided they have done the proper amount of work, that is, have been run under satisfactory conditions of speed and feed.

In the proper design of a tool, with angles to suit the work, there are four points to be remembered, namely: cutting capacity, that is, as the machinist would say, to "dig in"; the right angle of relief or clearance; proper strength; and durability or lasting quality of edge and point.

That these are not simply distinctions without a difference is seen if we analyze the question a moment. Cutting capacity is the tendency to dig into the work, to bury itself in the metal. This is directly opposed by the greater or less angle of clearance or relief. The tendency to bury itself in the work is due to the "rake" and the top angle, but principally to the rake in a slide tool and the top angle in a cutting-down tool.

These points will be clear upon reference to the engraving, in which Fig. 188 show the angles for a slide tool, and Fig. 189 those for a cutting-down tool.

As to the proper strength. The tool will be much stronger with more obtuse angles, yet more obtuse angles will be to the injury of its other qualities. Again, if the point or the edge is too keen, that is, at too acute an angle, its strength and durability are both jeopardized.

Hence we are forced to the conclusion that the form of the tool is not only largely governed by the kind and quality of the material to be acted upon, but is in itself, by reason of the conditions of its construction and use, very largely a question of compromises on the one side or the other, and frequently on both.

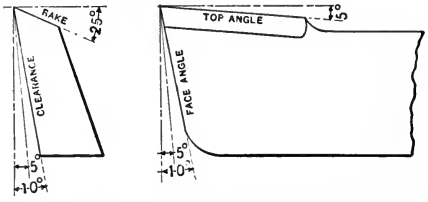


FIG. 188. — The Proper Angles for a Side Tool.

Referring again to Fig. 188 showing a side tool, and Fig. 189 showing a cutting-down tool, both of which are types of nearly all the various forms, attention is called to the various angles and their designations, which will apply equally well to all cutting-tools.

It will be seen that the clearance angle may be anywhere between a vertical line and 10 degrees from it. The face angle may have a like variation although we frequently see tools having an angle as great as 25 degrees. The "rake" or top cutting angle will be any angle from horizontal to 25 degrees, seldom more.

In a general way it may be said that in cutting steel the softer the material the more acute may be the angles, and that for very hard steel the angles must be very obtuse.

For cutting wrought iron the tool with angles too acute is liable to bury itself in the work and break, on account of the fibrous nature of the material.

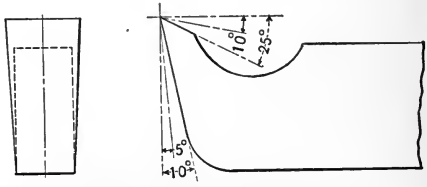


FIG. 189. — The Proper Angles for a Cutting-down Tool.

Again, in tools for brass work the angles will be very slight, otherwise the tool will plunge into the work and spoil it. It is a common saying in the shop, when the relative angles of tools for steel and brass are discussed, "Whatever you do for a steel tool, do the opposite for a brass tool." (The metals mentioned being those to be machined, of course.) And this is literally true as far as angles are concerned.

In the general working of steel and cast iron in many shops where

the workmen get their tools from the tool-room ready ground, the tool angles are the same for both metals and of all degrees of hardness, unless the foreman has special work to do requiring a special form of tool. Another set of tool angles are used for brass and bronze.

When bronze is very tough as well as hard, a special form of tool will be required, and this will sometimes very nearly approach the form of a tool for turning steel, including considerable rake and top angle. Often a diamond-point tool is used. (See Nos. 4 and 5 in Fig. 187.)

Tools are of two general classes according to their use, that is, for roughing and for finishing. The former must be made mostly for strength and are intended for deep cuts, coarse feeds, and slower rates of speed; while the finishing tools are for high speeds, fine feeds, and shallow cuts. Fine feeds are not, however, always used, as it is a common condition to use very light, scraping cuts, with a broad tool and a coarse feed. This is notably the case in finishing the inside of engine cylinders. The author has seen such a cut of nearly an inch feed, the tool being very carefully ground and acting more as a scraper than a cutting-tool. In this case the angles of the tool were very slight.

On outside work, that is, *turning* rather than boring, a finishing tool with a broad cutting edge is frequently made of an inverted U-shaped form and called a "spring tool," or a "goose-neck," which is shown in Fig. 190, the cutting-edge A being nearly straight across, or parallel with the surface of the work. When there seems to be too much "spring" in the action of the tool, a small block of wood is inserted at B, to furnish some support for the cutting edge and prevent chattering.

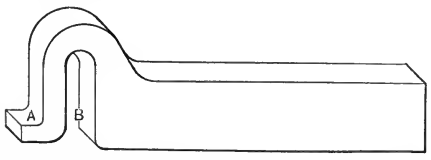


FIG. 190. — A Spring Tool or "Gooseneck."

This form of tool is not nearly as much used as formerly. In fact the later development of turning tools has been toward more simple forms, which, under modern conditions, seem better adapted to the general line of work.

While there are still very many of the ordinary lathe tools such as has just been described, that are in every-day use in nearly all

shops, the use of tool-holders, designed for holding tools made from small square or round rods of tool steel, has very much increased.

This innovation was started before the advent of the now well-known "self-hardening," or "high-speed" tool steels, that have so changed machine shop conditions and which followed the introduction of "Mushet" steel a number of years ago.

These tool-holders have been made in great variety and profusion and much ingenuity has been displayed in producing what each maker thinks is at once the most convenient, the strongest, and the best.

Some of these holders use tools made by simply grinding a slight notch in the bar and breaking off pieces of the proper lengths, whose ends are ground to the desired form, while others require a special form of cutting-tool that is usually drop forged, fitted, and tempered. It is fair to assume that on general principles and for general use the tools made from a bar will be the most useful, since

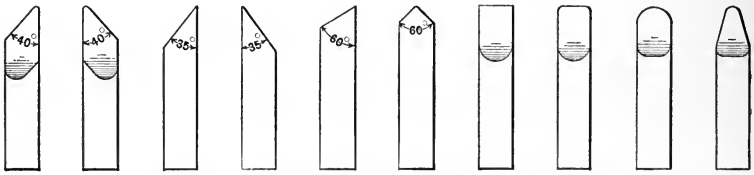


FIG. 191. — A Set of Ten Tools for a Tool-Holder.

it is always the most convenient. The machinist having a bar of tool steel of the proper size may produce tools of any form, and to fit any of his different tool-holders, according to which is best suited to his particular work.

The matter of grinding these tools is a very simple one. The regular shapes, and about all the shapes that will be needed, are shown in the engraving, Fig. 191, in which the angle is specified. Thread tools may, of course, be added to the list, and so also may some forms of inside boring and threading tools.

The dimensions of the steel used for these tools for light lathe work is $\frac{5}{16}$ inch and $\frac{1}{4}$ inch square. For medium lathe work, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$ inch square. For heavy lathe work, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{8}$ inch square.

There are many different brands and grades of so-called high-

speed or self-hardening steel. As between the leading brands there is very little difference in efficiency; some excelling slightly in one respect, or upon one class of materials to be machined, while another brand seems to work better on another.

As to the best form of tool-holder, there will, of course, be honest differences of opinion, and each machinist will have his favorite forms.

Probably there are more Armstrong tool-holders used than any other, and in Fig. 192 is given views of their usual forms. Their uses are plainly indicted by their names and forms.

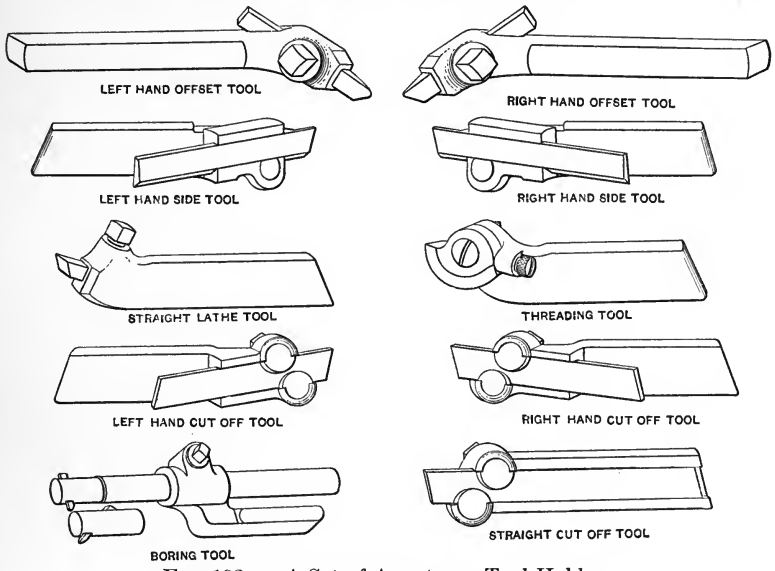


FIG. 192. — A Set of Armstrong Tool-Holders.

In Fig. 193 is shown at A a good form of tool-holder for regular straight work. At B is shown a tool-holder and tool for cutting threads. It will be seen that as this tool is of parallel form throughout its length, it is only necessary to grind off the top as it becomes dulled, and raise it to the proper position to compensate for the amount ground away, in order to always have a fresh surface and of proper cutting form and angle.

The economy of the use of tool-holders should be apparent to any one who studies the conditions even superficially.

The one fact that by their use the time and expense of the forging

and re-forging of tools is reduced to a minimum, and in fact may be almost eliminated, the tools to be so treated consisting only of a very few special tools for special jobs that cannot be conveniently reached by such tools as may be used in the tool-holders, is amply sufficient to warrant their use in every shop.

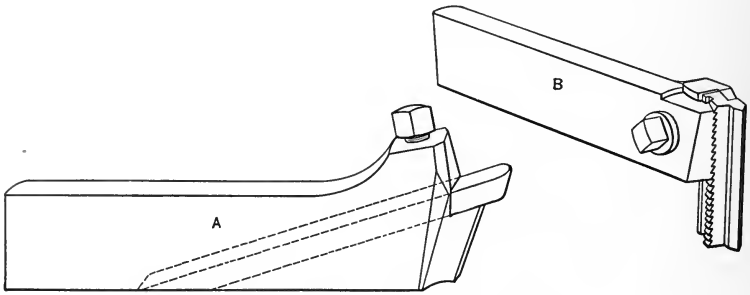


FIG. 193. — The Champion Tool-Holder.

The facility with which tools of different shapes that may be required can be produced is also an important reason for their use.

Another reason is that when the shop is once equipped with tool-holders, the cost for the steel for making the tools is very slight as compared with the heavy forged tools formerly used.

The modern demand for high-speed steel for lathe tools and its high price makes it necessary, from reasons of economy, to use small tools; hence tool-holders.

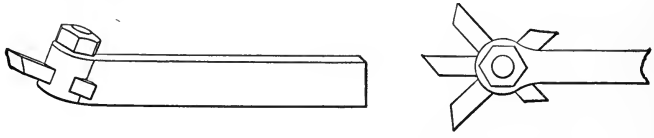


FIG. 194. — The "Three-in-one" Tool-Holder.

In reference to the use of high-speed steel in a very large and general way, for all classes of work upon which it is possible to use it, there seems to be no doubt. It has been proven many times, in many places, under many conditions and on almost every conceivable material that has to be handled in machine tools, that it has "come to stay" and that any information regarding it is of practical use.

The following remarks, giving the experience of one practical

and observing machinist whose name, unfortunately, is not at hand so that proper credit can be given him, are here introduced as being valuable in this connection, and practical from the machine shop point of view:

"The first thing is to make up one's mind as to the quality or kind of steel to use, which means to be satisfied with the steel which has been found to work best in one's own shop. This has been a difficult matter for superintendents and foremen to decide, because it is so hard to discover the best way to determine which steel will do the most work, and experience has taught most of us that any of our high-speed steels, when properly treated, will do considerably more work than the machine is capable of.

"I do not think it advisable to have too many different kinds of stock in the works; results depend entirely upon the way of forging and treating the tool. If the tool-maker is familiar with one or two grades of the best high-speed steel, and the quality is found satisfactory, and bringing about the best results that the machines can stand up to, these are the steels that should be adopted.

"Each of these steels must be treated differently, and if the tool-maker succeeds in treating one grade properly and understanding it thoroughly, it means much time saved and better results in the shop.

" In introducing the use of high-speed steel in a shop, like everything else that is to be a success, one must start right. That is, the work should be undertaken by some responsible person — superintendent, foreman or speed boss, in other words, the man who is responsible for the work turned out in the machine shop. All tools, of course, have some particular way of treating, which should be understood by the person in charge. Now it is 'up to the forger.'

"The person in charge should see that the tool has its proper treatment, as success in most cases lies with the treatment. When the tool is finished, and the superintendent or foreman is satisfied that it has been properly treated in accordance with directions, it is ready for grinding and for making a test. It should be ground on a wet emery wheel, and care taken to heat the tool just so it can be touched with the fingers.

"The tool once ground and ready to do the work, the question often arises, 'What lathe, planer, or machine are we going to put

it into?' In most cases when a new tool is tried, it is put in a lathe, to do turning; so naturally the superintendent or foreman would pick out the best lathe that was in the shop, *i. e.*, the lathe that was considered to have the most power.

"Being now ready to make the test, it is generally tried on steel; that is considered by most superintendents and foremen the severest test to make. Take a piece of steel of almost any diameter, and of the quality most used in the shop, and prepare to take the cut. It seems to puzzle most every foreman to know just what to do and where to start. I speak now of what I have seen, and of the men who are sometimes sent by the steel makers to demonstrate the use of their steels.

"I think the proper way is to get at least one dozen shafts of a standard size that are used in the regular line of product, and to first look up the exact time it took to finish or rough off the previous lot; then to determine about what percentage of time would be considered a fair gain to warrant adopting the steel, based on the price per pound of the steel being used. Let it be based at 25 per cent, which I find in most shops can be accomplished, and the lathe be speeded up faster than when the last lot was turned, starting with the same feed and about the same cut, which most any lathe will stand. The superintendent finds, after he has roughed off about two or three pieces, that the tool seems to stand up all right.

"The next step is to find out about the speeds and feeds. The first thing is to increase the feed with the same speed the machine is running at. In most cases which I have seen, after the tool has traveled a certain distance the cutting edge would break or crumble, and the foreman would say, 'Just as I expected. All this high-speed steel will do the same thing!' forgetting he had just been doing over 25 per cent more work than ever before, without the least bit of trouble.

"Now the tool is taken out and looked over, and it is found that a portion of its cutting edge has been broken off. Here is where most foremen make a mistake; they take the tool back to the forger or tool dresser to have it re-dressed and treated over. If it is only broken off slightly and can be ground, even if it take ten or fifteen minutes to grind, it should be done by all means. My

experience has taught me it will prove a better tool than before, but care must be taken not to overheat in grinding.

"The tool is now put back in the lathe, which is started again; and generally, to one's astonishment, it will be found that the tool will stand up all right. One should not be too anxious to break the tool again (!), but should turn up two or three more pieces with an increase of feed, keeping a record of the time it takes to turn up each piece.

"Once convinced that the tool will stay up all right with the increase of feed, the foreman can increase the speed one step on the cone. About the time this is done, it is found either that the belt slips, the lathe is stalled, or the countershaft will not drive. (It is my opinion that in most all machines which have been built up to a year or so ago the countershafts are not strong enough in comparison with the machine tools.) Now, no doubt if these things had not occurred the tool would have done better; but in this case, reduce the speed, and finish the twelve shafts, which it will probably be found can be done without grinding the tool.

"When the shafts are all roughed off and finished, the foreman will find to his great astonishment that by actual time the lathe has produced over 25 to 40 per cent more work than ever before. I allude to the lathe using most all ordinary tool steels.

"At this point it is up to the superintendent to see just where he is at, and he finds in looking around his shop that there is hardly a machine that he can't speed up, but he also finds that the speeds on the countershafts are all too slow. This means that he has either got to increase his speed by increasing the main line, or buy new pulleys to increase his countershafts.

"In most instances it is advisable to increase the speed of the countershaft, but by doing this he generally finds that the countershaft will not stand the speed. If the machines are not too badly worn out, and he is satisfied that he can get at least 25 per cent more work out of the tool by increasing the counter speed, by all means let him get a new countershaft and treat each machine this way.

"No doubt the reader will know the results that some of us have arrived at in the last two years. In regard to cutting speeds and feeds there has been and always will be difference of opinion, and it is almost impossible to determine the right feeds and speeds, whether

it is for steel or cast iron, and for the operations of turning, planing, or milling; the work varies so in different shops, that is, regarding the construction of different pieces, the amount of metal there is to remove from each piece, and how accurately the work has to be done.

"There is no doubt in my mind that the makers of high-speed steel have awakened the management of different shops, and it is surprising the amount of work which can be accomplished even with the old machines, with very little redesigning. There is no question but that the machine shops which do very heavy work have not the necessary power for the use of high-speed steels, as the power should be used if the machines are old ones.

"Referring again to the question of grinding, I wish to state that this is a very important factor in the use of high-speed steels. I have seen much damage done to the tools, in many instances making it necessary to treat them over, and, as we all know, this takes much time. My recommendation for grinding is to let one man grind all the tools, and be responsible for them. When a lathe hand or a machine hand wants his tool ground, he simply gives it to the man who is responsible, and gets another the same size and shape, these being always kept ground and ready for service. In this way the tools are kept uniform and ground alike.

"In reference to the amount of work that can be accomplished on different machine tools, the writer finds that the feeds have been altogether too fine on most makes of machines up to the time that they were redesigned for high-speed work. Now it has been demonstrated that high-speed steel has come to stay, and we all know that it works better on roughing work than it does on finishing. If most of the product of the machine department is to be turned, it has come to the point where the majority of work must be ground; and this is the only way to get good and accurate work, especially where the strains of the cut spring the work. Moreover, as it is not necessary to straighten the work to any great extent, it certainly means a great saving, as many of our readers know. The writer is not a builder of grinders, but merely speaks of the saving it has been on his own work.

"Below is a fair average of the speeds that most any good make of lathe, planer, drill press or radial ought to stand when using

high-speed steel. Every lathe has a face-plate about the diameter of the swing or very near that. Take the peripheral speed of same by feet per minute; the use of a Warner cut-meter will give you the speeds instantly. This is one of the handiest little tools that can be obtained, and no machine shop is complete without it. The speed must be taken with the belt on the largest step of the cone, with the back gears in. The speed of the following sizes of lathes, taken from a large face-plate with the slowest speed, I find to work very well, and considerable saving has been effected even on old lathes. Of course the feeds will have to be determined by the amount of power available:

" 14-inch swing lathe; slowest speed with back gears in, 100 feet.
16-inch swing lathe; slowest speed with back gears in, 90 feet.
18-inch swing lathe; slowest speed with back gears in, 85 feet.
20-inch swing lathe; slowest speed with back gears in, 75 feet.
24-inch swing lathe; slowest speed with back gears in, 65 feet.
30-inch swing lathe; slowest speed with back gears in, 60 feet.
36-inch swing lathe; slowest speed with back gears in, 50 feet.
42-inch swing lathe; slowest speed with back gears in, 30 feet.

" Larger lathes in proportion.

" High-speed twist drills, drilling cast iron, ought to drill the following, if we have the power and feeds:

" $\frac{1}{2}$-inch diameter, speed 500 r.p.m., $3\frac{1}{4}$ inches deep in one minute.
$\frac{5}{8}$-inch diameter, speed 400 r.p.m., $2\frac{3}{4}$ inches deep in one minute.
$\frac{3}{4}$-inch diameter, speed 335 r.p.m., $2\frac{1}{2}$ inches deep in one minute.
$\frac{7}{8}$-inch diameter, speed 290 r.p.m., $2\frac{1}{4}$ inches deep in one minute.
1 -inch diameter, speed 250 r.p.m., $2\frac{1}{4}$ inches deep in one minute.
$1\frac{1}{8}$-inch diameter, speed 220 r.p.m., $2\frac{1}{8}$ inches deep in one minute.
$1\frac{1}{4}$-inch diameter, speed 200 r.p.m., 2 inches deep in one minute.
$1\frac{3}{8}$-inch diameter, speed 185 r.p.m., $1\frac{7}{8}$ inches deep in one minute.
$1\frac{1}{2}$-inch diameter, speed 175 r.p.m., $1\frac{3}{4}$ inches deep in one minute.

" Larger ones in proportion.

"These speeds are all based on a peripheral speed of 65 feet per minute. High-speed drills have done somewhat better than this, however, but taking into consideration the time of grinding, I find that this speed is a good average during a day's run."

Continuing the discussion of high-speed steel it may not be amiss to say that it is yet in its infancy, and as far as can now be judged it has a most brilliant future before it. It has its shortcoming as every comparatively new product has, but when we consider how long it took to develop "machinery steel" to its present condition, we must admit that high-speed steel has a record that its friends may be proud of.

One of its good friends, Mr. Walter Brown, has given us in the columns of "Machinery" some excellent ideas on this subject, in which he has taken much interest and of which he has made many valuable observations and suggestions. Among other good things be says:

"In spite of its shortcomings, however, it is very evidently the cutting-tool material of the future, both because of its superior qualities, all things considered, and of the likelihood that most of its present failings will be overcome as manufacturers get a better knowledge of its nature and behavior.

"The chief difficulty in the way of its use now is its exceeding brittleness. Many a user has become discouraged with the result of a few experiments and has, because of finding that it lacked the toughness of other steels, discarded its use entirely. More experience would, if intelligently obtained, have demonstrated without question the great value of this new product of the metallurgist's skill.

"The question of brittleness is largely a question of treatment; and intelligent experience will very largely obviate the difficulty so that it will be tough enough to stand up under any proper conditions of work. Every tool-dresser knows how to handle carbon tool steels, and is guided by his knowledge of their qualities at different temperatures as indicated by their varying colors. When he gets a high-speed steel he naturally treats it much as he would carbon steel.

"This is where most of the trouble begins. The smith must learn an entirely different set of color values and methods of treatment. He thinks that if he has succeeded in getting a hardness greater than that of his file, he has done his job. That, however, has nothing to do with the fitness of the tool. I have known cases (with a certain make of steel) where the tool would do the best work while still soft enough to take a good Swiss file.

"In other steels a similar degree of softness, or even a degree of hardness much greater than that of ordinary steel, would not work, the tool 'gumming up' and rapidly burning up. The whole secret lies in getting the tool to such a heat, in the process of hardening, that the constituent molecules are mobile, and then 'drawing' it to the right point.

"When the tool-maker has mastered this secret, he can produce a tool of high-speed steel as tough as any of carbon steel. The mastering of it is largely a matter of experience. Our own experiences have been so interesting and successful that I have thought they might prove of help to others, and I submit them herewith.

"The tools should be placed in a pipe or box, well surrounded with small pieces of coke, the packing case then being sealed up with fire clay. Small holes must be left for the escape of gases, otherwise the clay will blow out. The heating furnace should have been previously heated to a white heat. The packing case is left in the heat from one to three hours, according to size. When removed from the furnace, the box should be as near the bath of fish oil as may be, so that there will be no unnecessary delay in bringing from the gases of the packing case to the bath.

"Exposure to the air not only causes scale, and therefore variation in size, but tends to affect the precision of the hardening process. Observance of this caution will prevent a variation of more than a thousandth of an inch in tools of moderate size. Carbon steel usually varies several thousandths as a result of hardening.

"The method of packing will depend somewhat upon the shape of the tool. It is important to pack in such a way that all tools packed in one case be so placed as to be handled very quickly, and at once plunged into the bath, to prevent scaling by reason of contact with the air, as explained above. In case of milling cutters and key-seat cutters, a good way is to suspend them all from a rod, each separated from its neighbors by a slight space, sufficient to allow a free circulation of oil when plunged. Neglect of this caution will be very likely to cause cracks, from the unequal contraction of the cutters, the outer edges only being brought into immediate contact with the bath, and therefore shrinking more rapidly than the interior parts.

"For taps, drills, and similar shaped tools, this hardening leaves the steel too brittle, and as soon as the tool has become a little dull it breaks off. To avoid this the tool can be drawn as can a carbon-steel tool. But here, too, a new set of color scales must be learned. The blue heat of carbon steel is not enough of the high-speed steel. The heat must be carried on until the metal reaches a greenish tinge. It is then allowed to cool in a dry place free from air drafts.

"It is now much tougher and softer than before. In case it needs still further softening, it can be done by reheating, bringing it to a faint red, dull enough to be perceptible only in a dark place (an empty nail keg is convenient for this use) and then cooled as before. We have made taps as small as $\frac{5}{16}$ inch in diameter to be used in an automatic nut tapping machine, about the hardest work to which a tap can be put, with gratifying results.

"In the test three taps cut 92,000 nuts, an average of almost 31,000 nuts per tap; with carbon steel taps we cut 6,000 nuts per tap. No effort was made to speed up the machine, the test being one of durability only. The carbon steel taps cost about ten cents, and the high-speed taps about forty, or four times as much. The latter, however, cut about five times as many nuts. Besides this, there is also to be taken into account the more important saving in the time used formerly for stopping the machine, and removing and grinding taps, which is five times as great when carbon steel taps are used.

"This is not mentioned as a particularly demonstrative test, but merely to show that high-speed steel can be profitably used for small tools, if properly treated. Another place where we are using high-speed steel with profit and satisfaction in small tools is in drills. The saving here is very marked; but the statements and claims of several makers of such drills is not verified by our experience. We find that we can run such a drill at about double the speed of the ordinary drill, and at the same time cut more holes.

"Makers of the new steels are in the habit of making large claims as to speeds attainable. We have tried about every such steel on the market, giving each a thorough test. Our experience usually bears out the moderate statements, and sometimes the extravagant ones, put forth by some makers as to what is possible. For

instance, we have cut a $\frac{1}{16}$ chip, $\frac{1}{32}$ feed, at a rate of 266 feet per minute peripheral speed, from a rod of machine steel.

"Such speeds are possible for short periods; but whoever buys a rapid cutting steel with the expectation of maintaining such speed will be sadly disappointed. With a fine feed, even four hundred feet per minute can be cut under very favorable circumstances. But think of the chip that comes off! In case of steel the chip is no such thing as we are accustomed to, breaking into short pieces and dropping into the box below.

"At a speed of, say, two hundred feet per minute, the chip comes writhing and twisting, almost red hot, in a continuous length, shooting here and there, everywhere but the chip box; and quick must be the workman that manages to keep well out of the way of it, for it 'sticketh like a brother' when once he gets tangled in it.

"Possibly, in time, a way will be found to take care of such chips. Until this is done, however, a moderate speed is most desirable. We find that on steel, where there is no considerable thickness of metal to remove, a speed of one hundred feet a minute is very satisfactory. This allows taking care of chips, and the tools stand up well under it. In turning gray iron, where the scale is to be removed, about seventy feet per minute is giving us the best results. Naturally, however, there being so many different kinds of materials to work up, and each one of these varying more or less themselves, there can be no set rule for speed. Each job will work out a rate for itself. The main thing is to get out the job as fast and as well as possible, and at the same time to lose as little time as may be in grinding the tool.

"Another word about the saving to be effected. This will depend among other things upon the number of machines that are run. If only one machine runs on a job, there will not be a saving of two thirds simply because the speed is trebled. It must be remembered that perhaps 50 per cent of the time for doing a job on a single machine is used in jigging the piece and setting the tool.

"The high initial cost of the new steels has made it necessary to devise means for reducing the quantity of metal in the tools used. The result has been the production of some very ingenious schemes for holding cutters. The lathe tool holder is, of course, familiar to all. Milling cutters, hollow mills, and reamers with inserted

teeth, are scarcely less familiar. It is now true that we are making all these tools with inserted cutters of rapid cutting steel at less cost than the old carbon steel tools. At the same time they are doing from three to ten times the work, and at a much greater speed."

The question of speeds and feeds is an important one in connection with that of lathe tools, whether the old carbon steel is used or the new high-speed steel known as self-hardening is that selected.

As has been said in the observation on the form and qualities of tools, a great deal depends, not only on the *kind* of metal worked, but also on the *quality* of the particular kind that is to be machined.

With the old form of tools made from the old carbon steels, cast iron was turned at a speed of from 20 to 25 feet per minute; soft steel, 25 to 30 feet; wrought iron, 35 to 45 feet; and ordinary brass at from 50 to 100 feet.

With the present tools and methods such speeds are considered child's play, and the speeds at which different materials are turned, assuming a medium grade of metal, will more likely be given as

Soft Cast Iron	50 to	60	feet.
Hard Cast Iron	20 to	40	"
Hard Cast Steel	30 to	40	"
Soft Machine Steel	30 to	40	"
Hard Machine Steel	20 to	30	"
Wrought Iron	35 to	45	"
Tool Steel, Annealed	20 to	30	"
Tool Steel, not Annealed	15 to	20	"
Soft Brass	110 to	130	"
Hard Brass	90 to	110	"
Bronze	60 to	80	"
Bronze, Gun Metal	40 to	60	"
Grey or Red Fiber	40 to	60	"

The feeds will not vary in the same proportion as the speeds, or in fact bear any fixed relation to them.

A prominent writer on this subject says that: "An important point is, that other conditions being equal, the increase of speed involves a diminution of feed. Hence it is not possible to reduce the question of speeds and feeds to formulæ, or tables."

This is hardly correct as to the fact of the inverse relation of speeds and feeds under varying circumstances, as the same author admits further on by saying: "Each class or job must be settled by

itself in the practice of any given shop." He might have said, with each different material, and as to whether it is a roughing, sizing, or finishing cut.

Some practical observations in point may not be amiss, as they are taken from actual practice and may be held as good mechanical data, with the use of high-speed steel.

Roughing cuts in soft cast iron may be made with a feed as coarse as 4 to 5 per inch, with a tool whose leading corner is slightly rounded.

Roughing cuts on soft machine steel forgings, 5 to 8 per inch.

Sizing cuts on soft cast iron, 12 to 16 per inch.

Sizing cuts on soft machine steel, 16 to 20 per inch.

Finishing cuts on soft cast iron, with a narrow-point tool, may be from 15 to 25 per inch.

Finishing cuts on soft machine steel, with a narrow-point tool, 20 to 40 per inch.

Finishing cuts on soft cast iron, with a wide point, practically straight-faced tool with corners slightly rounded, the feed may be, for soft cast iron, from 1 to 4 per inch.

Under like circumstances, for soft machine steel, the cut may be from 4 to 8 per inch.

In these different cuts the speeds may be substantially as stated in the table given above, except the last, in which case the speed must be very much slower, less than half the speeds there given.

Further than these figures it will be found difficult to set down a range of speeds and feeds that will be of any practical value. It must be left for the superintendents, foremen, and mechanical engineers in charge of work to determine these facts and to adopt such standards as may be found by actual experiment is most satisfactory under the circumstances and conditions governing the work, and which will, of course, include a careful study of the materials that are to be machined.

The lubrication of tools has a very considerable influence upon the performance of lathe tools, and when used should materially increase the output of the machines by permitting faster speeds, heavier cuts, and greater feeds. Lubrication prevents the friction that otherwise attends heavy cutting, and therefore prevents heating to both the work and the tool. A steady stream flowing upon

the cutting-tool will tend to carry away such heat as will, to a certain extent, always take place. Naturally a well lubricated tool will last longer in proper condition for cutting than one that is not lubricated, as the friction of the metal across the edge of the tool will be much less.

As to the kind of lubricant to be used, it will vary with the kind of metal to be machined and its condition. Cast iron will require no lubricant. In fact it is probable that any kind of a lubricant would be a detriment rather than a help when turning cast iron. The same may be said of ordinary yellow brass castings and the usual kinds of sheet brass, brass rods and tubes. But for bronze, and similar alloys containing a considerable portion of copper, it is always advisable to use a lubricant, and, if very hard and tough, oil is the proper lubricant. This is also true of the turning of wrought iron, malleable iron and steel, or steel castings.

As to the kind of oil most appropriate, it is well known that lard oil leads all others. On account of its high price, this oil is often replaced by a mixture of lard and other animal oils or fish oil. Mineral oil should not be used, as it fails to prevent the heating of the work and the tool. Neither should a mixture of animal and mineral oils be made for such a purpose.

For reasons of economy certain soapy mixtures are sold for these purposes. These are mixed with water to a consistency to flow freely, and often answer the purpose nearly as well as oil. They are more convenient and cleanly to use around the machine.

While it is convenient to purchase these compounds, a good one is easily made by boiling for half an hour or more one half pound of sal soda, one pint lard oil, one pint soft soap, and water sufficient to make twenty quarts. The soda should first be dissolved in the water, and the oil and soap added successively while the mixture is hot. Should the mixture prove too thick to run freely from a drip can, or to pass through a lubricating pump, hot water should be added until the desired consistency is obtained.

Any purchased preparation of this kind that has a tendency to rust the cast iron parts of the machine should be rejected, as it contains either acid or an excess of soda, and sometimes, even potash, all of which will be detrimental to the work and the machine as well as to the efficiency of the operations being performed. Trouble

will also be experienced with the pumps and pipes from becoming clogged by the undissolved portions of the compound.

As to the means used for applying the lubricant, the first and most simple is a small, round bristle brush. This will answer well enough for short jobs and for small parts, but for larger work is rather a tedious process, requiring the constant attention of the operator, and thus limiting him to the work of a single machine. Oil is the lubricant usually applied with a brush.

The gravity feed comes next in order. This is simply a "drip can," which is supported by a rod attached to the rear of the carriage or compound rest. This can, holding a quart or more, is provided with a bent tube having a faucet, or stop-cock, attached at or near the bottom. It is kept filled by the operator pouring from a tray under the work such portions of the lubricant as drip off the work.

As a constant stream of lubricant is always desirable, however large or small it may need to be, a small pump is resorted to. A small tank is located under the machine or near it, from which the pump draws its supply of the lubricant and forces it up through a jointed or flexible pipe to the tool. Its flow is regulated by a stop-cock as in the gravity feed.

The tank is usually made of cast iron, and is divided into two parts by a vertical plate reaching up to within two or three inches of the top of the tank. The lubricant, as it flows from the tool, carries with it many fine chips which flow into one of these compartments, where the chips fall to the bottom while the lubricant fills the compartment, flows over the vertical plate and into the other compartment where the clear liquid is drawn off by the pump. This method is an improvement over the perforated metal plate or the wire gauze strainer.

Usually these pumps and tanks may be purchased independently of a machine and attached in any manner desired. As the pumps are usually of the rotary type, they may be driven from a small pulley on the countershaft of the lathe if no special provision for them has been made on the machine itself.

While these lubricating devices are usually more appropriate for a turret lathe or similar machine than for an ordinary engine lathe, yet the class of work and the kind of material to be ma-

chined will be the deciding factor more often than the type of machine.

It will be often desirable to know the power which is being consumed in operating a lathe on certain work for which data is required. For most purposes this can be sufficiently approximated by calculating the power of the lathe from the width of the belt and its speed in feet per minute.

For such purposes it is usual among mechanical engineers to consider that a one-inch belt traveling a thousand feet per minute will transmit one horse-power. This will give us a key to the entire calculation.

For instance, if we have a piece of work 6 inches in diameter, we know that for every revolution it will move through a distance equal to its circumference, that is, 18.85 inches. If the cutting speed is 30 feet, or 360 inches, we can easily calculate that it must make 19.6 revolutions per minute. If the back gear ratio of the lathe is 12, and we are using the back gears, the cone must make 12 times as many revolutions as the piece of work, or 235.2 revolutions per minute. If the step of the cone on which the belt is running is 19 inches, it will be practically 60 inches circumference, or 5 feet, and therefore the belt speed will be 1176.6 feet per minute, or 1.176 horse-power for every inch in width of belt. Now, assuming that the belt is 4 inches wide, we shall be using 4.7 horse-power, if we force the cut up to the full capacity of the belt to drive it.

This calculation is for single belts. A double belt is expected to transmit double the power.

It would be very interesting if we could make a table giving the power required to drive the lathe on all different diameters, for all different kinds and qualities of metal, when turned with all different forms of tools made from all different kinds of tool steels, and on all different designs of lathes.

It would, however, be an almost endless task and would be of very little practical value when it had been accomplished. The conditions as noted above, and which are all practical, every-day conditions, are so many and so various that there would be found very seldom a repetition of them in regular machine shop work.

To construct a table that should give the power required for different tools and metals worked upon in a certain shop, it would

be necessary to observe conditions, to collect and record data, and to make calculations from these individual conditions and circumstances, in this particular shop. And this table, while of considerable value in this shop, and interesting to any mechanical engineer or shop economist, would not be a safe guide in any other shop until corrected by the data made by an extended series of observations, the time and expense of which would be nearly equal to those necessary to produce the original table.

These remarks are not intended to discourage the desire to obtain such data. It is always commendable to search, observe, calculate, and "dig out" all these and similar facts relating to the performance of machine tools, and such habits should be encouraged in all who have to do with this work. No labor of this kind is lost, since every item of such work adds to the sum total of our information and enriches the subject for us, and gives us a more secure and confident hold on the important questions involved in it.

A still further reason for such observation and the recording of the data thus obtained is the constant changing of the design of machine tools, the constant changing of material to be worked upon, the infinite number of forms of the parts to be machined, and the thousand-and-one differing circumstances of their manufacture.

A recent writer whose name, unfortunately, is not given, in discussing the question of the power required for taking the cuts in different metals and the pressure in the tool says:

"The most complete information on this subject is contained in Flather's 'Dynamometers and the Transmission of Power,' in which are collected data from many tests upon various kinds of machine tools. Since the introduction of high-speed steel, however, conditions have changed so much that the deductions from the tables mentioned would be to a certain extent incorrect. Probably the most satisfactory way to determine the pressure on a tool is to obtain this from the power required to drive the machine when cutting. Knowing the horse-power, if we multiply this by 33,000 we have the foot pounds per minute; dividing this by the cutting speed in feet per minute will give the pressure on the tool, neglecting the power lost in overcoming the frictional or other resistances in the machine itself. In tests upon high-speed cutting steels at the Manchester Municipal School of Technology, to which we shall

presently refer, it was found that the power absorbed by the machine varied greatly with the temperature of the bearings and also with the speed. After the bearings become warm, the oil is more viscous, which makes an appreciable difference; and tests also show that it sometimes requires more power to run a lathe at high speed — as would be the case when filing a piece of work — than when taking a heavy cut at a slow speed. These facts indicate the degree of care necessary in arriving at reliable information upon the subject of your inquiry.

Referring to the tests in Flather's text-book, we find the following formulas deduced from average results, which give the horse-power required to remove a given weight of cast iron, wrought iron or steel:

For cast iron, horse-power equals	$.026 \times W$.
For wrought iron, horse-power equals	$.03 \times W$.
For steel, horse-power equals	$.044 \times W$.

"In each of these W is the weight in pounds of the metal removed per hour.

"The most complete information upon power required with high-speed steels is that obtained by the English tests at the Manchester Municipal School of Technology. These are very elaborate and cannot easily be summarized, but the following statement of results will answer our purpose and throw some light on the subject:

CUTTING SOFT STEEL

	Weight per Hour	Horse-Power
Light cut	105	3
Heavy cut	445	15

CUTTING CAST IRON

	Weight per Hour	Horse-Power
Light cut	42	1.7
Heavy cut	198	5.5

"Applying Flather's formulas to these results we find that for steel the horse-power required would be 4.6, instead of 3, for light cutting; and 19.6, instead of 15, for heavy cutting. In the case of cast iron we find the horse-power would be 1.1, instead of 1.7, for light cutting; and 5.15, in place of 5.5, for heavy cutting. This would indicate that Flather's formula for steel allows more power for soft steel than was shown to be actually required by the English tests, and will probably give ample power for a considerably harder

grade of steel. In the case of cast iron his formula appears to apply very closely, but giving results slightly too small.

From these comparisons it would seem that the rule to multiply the weight of metal removed per hour by .04 would give a safe value for the horse-power for both steel and iron.

Further examination of the results of the English tests shows that with the steel more metal was removed per horse-power when taking a heavy cut than when running at high speed and taking a light cut; while when cutting cast iron this condition was reversed.

It was found that the cutting force did not vary much with the speed, because at high speed the cuts were light while at low speed the cuts were deeper and taken with a heavier feed. The pressure on the tool increased very rapidly as the tool became dull; but when the tool was in good cutting condition the following pressures were recorded:

	Tons
For soft fluid compressed steel	115
For medium fluid compressed steel	108
For hard fluid compressed steel	150

	Tons
For soft cast iron	51
For medium cast iron	84
For hard cast iron	82

"It will be noted in reviewing these pressures that those for steel appear to be a little irregular, but they are recorded in the results of the experiments cited."

This interesting subject might, with profit, be pursued much further and such investigation is earnestly recommended to the seeker after facts in this respect; but the limits of space will not permit a more elaborate exposition in this chapter.

CHAPTER XII

TESTING A LATHE

Prime requisites of a good lathe. Importance of correct tests. The author's plan. Devices for testing alignment. Using the device. Adjustable straight-edge. Development of the plan. Special tools necessary. Proper fitting-up operations. Leveling up the lathe for testing. An inspector's blank. The inspector's duties. Testing lead screws. A device for the work. A micrometer surface gage. Its use in lathe testing. Proper paper for use in testing. Test piece for use on the face-plate. Testing the face-plate. A micrometer straight-edge. Allowable limits in testing different sized lathes. Inspection report on a lathe. Value of a complete and accurate report.

Before entering upon the consideration of the work of the lathe in all its varied phases and by the different methods that are appropriate for the many classes of work with which we have to deal, it would seem proper to discuss the methods of testing the lathe to ascertain its condition before putting work upon it.

In so doing we shall be able to direct attention to some of the prime requisites of a good lathe and how to ascertain whether the particular lathe in question possesses them or not. We should know whether the main spindle is exactly parallel with the V's or not, both in a horizontal and a vertical plane; to know whether the carriage is at exactly right angles to the V's or not; to know whether the head center and the tail center are exactly in line or not; and so on through the many requisite features of a good lathe; one that will "turn straight, face flat and bore true."

The plan that will be given and the tools and implements used were devised by the author, who used them in testing hundreds of lathes and found them accurate and practical, and confidently recommends them to any mechanic having such duties to perform and a desire to perform that duty in the best and most accurate

manner, and to make the reports on the machines he tests of such a nature as to command the confidence and respect alike of manufacturer, purchaser, and user.

At this time, when such extreme accuracy in machine tools is demanded, when it may be said that the machine tool that could be sold as a fairly good tool ten or even five years ago could scarcely be given away now; when a buyer critically tests every requirement of the machine he buys, and oftentimes almost literally dissects it, it becomes necessary to adopt such methods and to provide such appliances as will insure a practical demonstration of its accuracy. Although the lathe is the oldest known machine tool we have, we are far from knowing all its capabilities and possibilities as yet, and each year finds some added good points brought out by the many workers in the field.

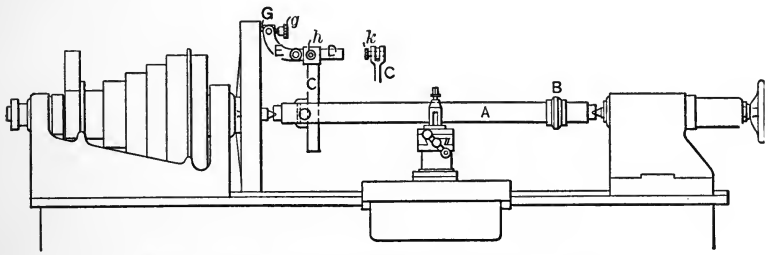


FIG. 195. — Testing Alignment of Lathe Centers.

But whatever may be its special form or construction it becomes a matter of vital importance to practically test it before it leaves the hands of the manufacturer.

And that condition or those qualities which are important to the builders of machine tools are equally important to the purchaser who "pays good money and expects a good machine." The success of the mechanic who runs the machine, and the officials under whom he works, is a matter that has its important bearing upon the question, since we cannot expect a high degree of efficiency without good machines.

Therefore the proper appliances for making accurate tests of lathes are here presented.

Figure 195 shows the general construction of the testing device, as applied to a lathe, for ascertaining the alignment of the head and

tail spindles. An arbor, A, is preferably constructed of thick steel tubing with hardened steel plugs fitted to and forced into the ends, which have been previously bored out. This arbor is ground true and should be from 4 to 6 inches longer than the diameter of the largest face-plate to be tested.

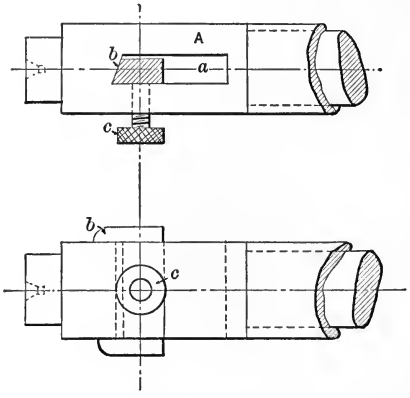


Fig. 196. — Details of the Testing Bar.

Upon the arbor is accurately fitted a hardened and ground collar B. At the end of the arbor next to the face-plate the plug has a mortise *a*, made square at one end and at an angle at the other, as shown in Fig. 196. At the angled end is fitted a key *b*, with the usual projections, to prevent it from dropping out, and controlled by the thumb-screw *c*. Passing through the mortise *a* is a bar C, carrying at its outer end a micrometer screw device, represented in detail in Fig. 197. This consists of a bar D, of a size convenient to hold in the tool-post of the lathe as well as in the slotted end of the bar C, where it is clamped by the thumb-screw *k*.

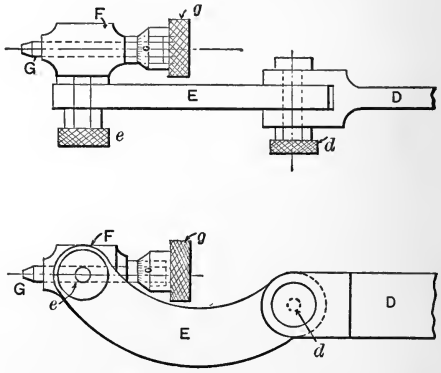


Fig. 197. — Micrometer in Position to Test.

Pivoted to the bar D is the curved bar E, having pivoted to it the block F, which carries the micrometer screw G, operated in the usual manner. The knurled thumb-screws *d*, *e*, fix these joints in any desired position.

The use of this apparatus is as follows: Place the arbor in the lathe, slide the collar B up near the mortise *a*, clamp the micrometer device in the tool-post in the position shown in the upper figure in Fig. 198, and bring the point of the micrometer screw

down upon the collar B, rotating the latter slightly to get the pressure just right. Slide the collar B to near the tail-stock, move the carriage down opposite to it and note if the micrometer screw rests upon the collar as before. If not, note on the graduations of the micrometer the amount that the tail spindle is high or low.

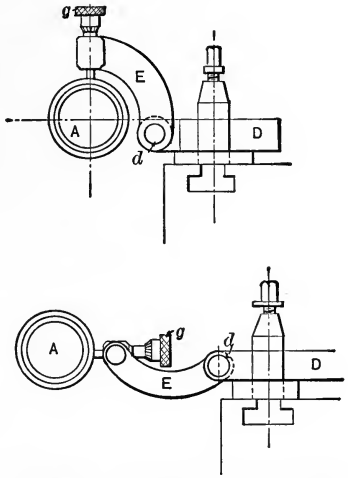


Fig. 198. — Testing Alignment of the Tail-Stock Spindle.

It is assumed that the centers have previously lined fairly well sidewise. To set them accurately the same method as above is used, setting the micrometer device as shown in the lower figure in Fig. 198.

Supposing that the centers of the lathe have been found to line vertically and horizontally correct, we now desire to know if the back box of the head spindle is set in exact prolongation of the line of centers. Place the bar C in position and clamp the micrometer device in it, as shown in Fig. 195. Slowly revolve the tram device thus arranged, setting the micrometer screw to the nearest point in contact with the face-plate. Continue the revolution and with the micrometer screw ascertain the exact variations of the face-plate

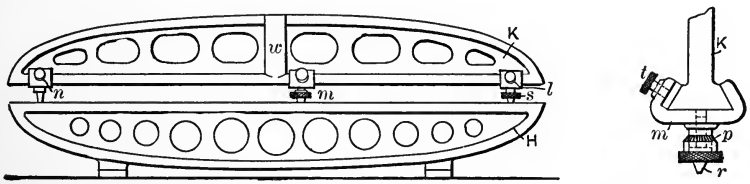


Fig. 199. — Straight-Edge for Testing the Cross Slide.

from a perfect right angle with the line of centers. Having determined the accuracy of alignment of the lathe, we now desire to test its accuracy of facing — whether it will face up a piece concave, convex, or exactly true, and to note the extent of the variation.

Figure 199 shows an adjustable straight-edge for this purpose.

H is a permanent straight-edge used only for adjusting the one applied to the face-plate. This is shown at K and has its lower edge formed as shown in the section at the right, and has three blocks, *l*, *m*, and *n*, sliding upon it and fixed at any point by the thumb-screw *t*. These blocks are set at such distances apart as will accommodate the size of the face-plate to be tested. The block *n* carries a fixed point, about $\frac{3}{16}$ of an inch in diameter at the point. The block *l* carries a plain screw point *s*, used to adjust the device so that the micrometer screw *r* of the block *m* may be adjusted at zero. To adjust these set the micrometer screw at zero and then bring the screw *s* up or down till all these points rest properly on the permanent straight-edge.

To apply the device to the face-plate to be tested the surface *w* is placed downward on a short arbor, taking the place of the head center of the lathe and projecting about 6 inches from the face-plate. This not only furnishes a convenient support, but keeps the contact points at right angles to the face-plate. Keeping the points of the block *n* and the adjusting screw *s* in contact with the face-plate, the micrometer screw *r* may be set to the convexity or concavity of the plate, and the error read on the micrometer graduations *p*, in thousands of an inch, or even much finer.

A subject thus important will necessarily have its developments and these should be made by actual experience in a practical manner. In developing these methods of testing a lathe, further instruments were necessary and are therefore described. In some cases where there are two methods of test, one of these was used and in some cases the other. Again, both were used and checked against each other.

The special tools necessary for determining the accuracy of an engine lathe must, of course, be accurate and reliable, but they need not for this reason be elaborate or expensive, as the illustrations accompanying this article will readily show. Their description and use will be fully explained as the process of inspection is proceeded with in the matter which follows.

It is assumed that the lathe bed, as well as the head-stock, tail-stock and carriage, have been properly planed, the V's shaped to the proper angle, and that the V's of the bed have been scraped straight and true, removing as little of the metal as possible. The head-

stock, tail-stock, and carrriage should now be carefully scraped to fit the V's of the bed. Their fair bearing may be easily ascertained by rubbing on a little of a mixture of the dry, red pigment commonly known among painters as "princess red," or some similar dry color, mixed with a small portion of any oil that may be convenient. The above color will be found to have this convenience: it will show almost black where the pressure is very severe and correspondingly lighter where the contact is less perfect. The scraping should be continued until the contact spots do not exceed $\frac{3}{4}$ inch from center to center, and the inspector should assure himself of this fact before these parts are finally fixed in position.

The carriage should be run back and forth along the length of the bed to detect any slight curves that the bed may have taken since it was planed, and if any are found they should be corrected by scraping. Of course the bed should be carefully leveled up and kept so during the time this scraping and fitting is going on.

When the lathe is finally "set up" or erected, great care should be taken to have it in as firm a foundation as is possible, and this requirement becomes all the more important as the lathe is larger and heavier. The bed should be carefully leveled both longitudinally and transversely, applying the level to the tops of the V's at points not over four feet apart for large and heavy lathes, and not over three feet for small and medium sized ones. If this is not carefully attended to it will be difficult to determine with any reasonable degree of accuracy whether or not the lathe will bore truly, as a slight change in the tops of the V's, throwing them out of a true plane, will defeat the test.

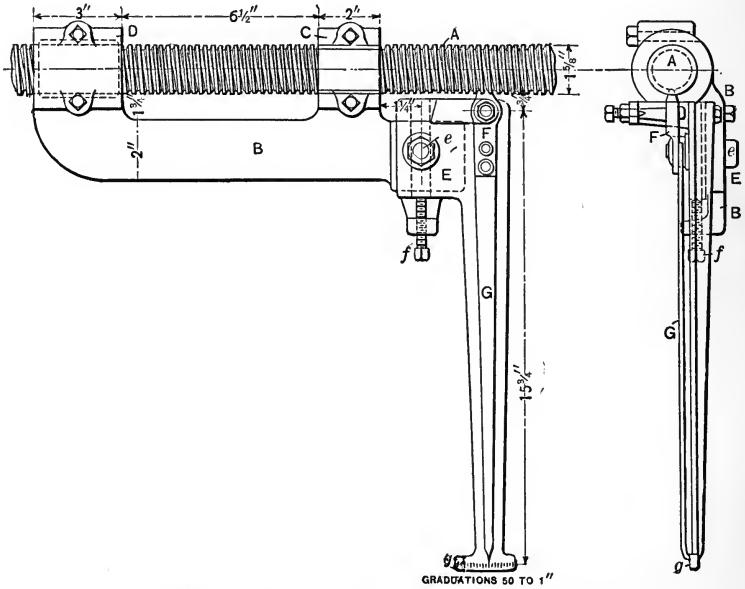
Neither can proper tests by means of the carriage be made if the V's on the bed are not so carefully leveled up as to be correctly in the same plane.

Before proceeding to further describe this system of lathe testing, attention is called to the accompanying blank report for properly recording the results of the inspection. It will be noticed that it is quite thorough, but a long experience in machine tool work brings us to the conclusion that there is not a superfluous observation or requirement in it. And it is recommended that lathe builders send a signed copy of this report to the customer who purchases the lathe, for his information and guidance

in testing the lathe for himself when he has it set up in his own shop.

There are many items of an inspector's duty not here enumerated which, in a shop properly arranged and managed, will have been attended to as the parts are being made and assembled. This relates only to the performance and outward condition of the lathe when ready for its final inspection.

Lead screws should be tested before they are put into the lathe of which they are to become a part. They should be held on centers


3"
6½"
2"
D
C
A
B
E
F
G
e
f
1⅝"
1¼"
2"
1⅝"
1⅝"
1⅝

bored large enough to allow of a suitable bushing being introduced. The frame B of the device is extended to the right to form a grooved support for the adjustable arm E, secured by the bolt *e* and adjusted by the screw *f*. This arm is extended to form a graduated segment at *g*. Pivoted in the arm E is the indicating lever F, whose front end is formed to fit the thread of the lead screw A, and to whose rear end is fixed the indicating arm G, whose point rests on the graduations at *g*.

The leverage and graduations are so arranged that thousandths of an inch are indicated by lines, and a much smaller fraction may be readily perceived. In using this device that portion of the frame B between the bearings C, D, rests on the top of the compound rest, the lathe being arranged for the same pitch as the lead screw to be tested. The screws holding down the caps of the bearings C, D, are set up just close enough to insure a proper fit. The object of using a babbitted nut in the bearing D and applying the indicating lever F at some distance from it is threefold. The influence of the lead screw of the lathe in use is not felt, there is very little friction on the point of the indicating lever F, and the relative inequalities of the thread of the lead screw to be tested are rendered more obvious.

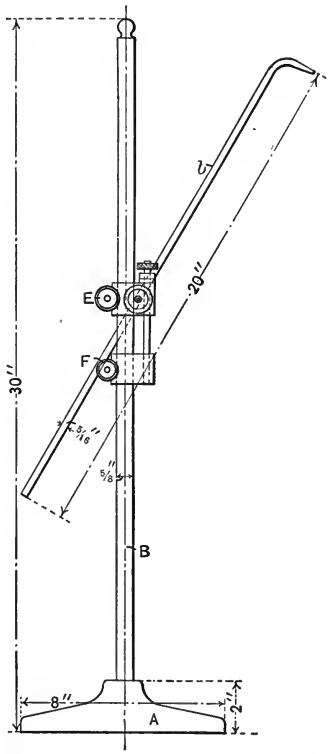


FIG. 201. — Micrometer Surface Gage.

Another very important and useful instrument in lathe testing is the micrometer surface gage, which is shown in Figs. 201 and 202, in which all principal dimensions are given.

The base A is of cast iron, the supporting rod B and the pointer *b* are of Crescent steel drill rod, and the other parts (excepting the spiral spring) are of tool steel. Its construction is readily under-

stood from the drawings, special attention being called to the arrangement for securing the pointer *b*, as shown in section in Fig. 202, by means of the conically formed thumb-nut G, its clamping bolt H, and the conically formed receiver.

The blocks C, D, are connected by the rod K, whose lower end is fixed in the block D and whose upper end passes up through the block C, where it is cut with a thread 40 to the inch, and provided with a graduated thumb-nut L, by means of which we may read thousandths of an inch, and even the quarters of that fraction are readily determined.

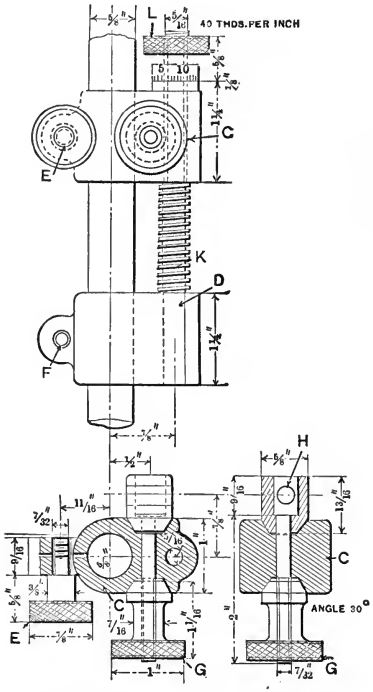


FIG. 202. — Details of Micrometer Surface Gage.

Blocks C and D are forced apart by the spiral spring surrounding the rod K. In the use of this device the block D is secured by the thumb-screw F. The pointer *b* is then brought down near the work and is secured by the thumb-nut G. The thumb-nut E is now tightened just enough to hold it firmly, and the final adjustment made by means of the graduated thumb-nut L.

The lathe being ready for testing and the face-plate having been faced off, we begin with the test for alignment, as shown in Fig. 203, which is a rear elevation of a lathe ready to be tested, and Fig. 204 a plan of the same.

To ascertain the vertical alignment of the head spindle we place an accurately ground and properly fitted test bar A in the center hole of the head spindle and place the micrometer surface gage on the lathe V's as shown in Fig. 203, first applying the pointer *b* at a point near the face-plate and then near the outer end of the test bar, as shown by dotted lines, using the micrometer-adjusting nut

L to ascertain the difference, if any. To render the touch of the pointer more sensitive a slip of paper should be drawn carefully between the test bar and the pointer. The best paper for this purpose is a hard calendered linen typewriter paper, three thousandths of an inch thick, as this paper runs very uniform in thickness.

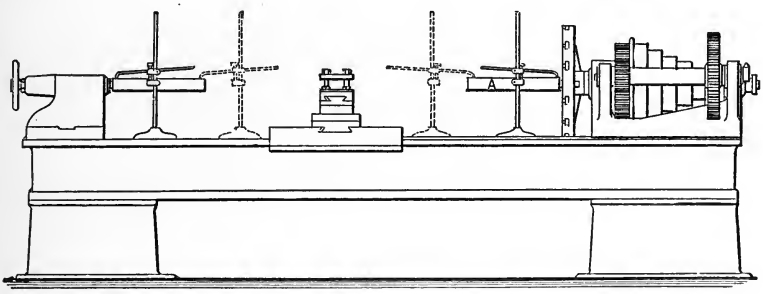


FIG. 203. — Rear Elevation of Lathe being Tested for Alignment of Head-Stock and Tail-Stock Spindles.

If the inner and outer V's of the lathe are not of the same height, a parallel bar should be laid across the V's and the micrometer surface gage placed upon it. In any event much care should be exercised to be sure that the gage base sits fairly on its support, as a slight scratch, or a burr, or the least bit of dirt, will defeat the object of the test.

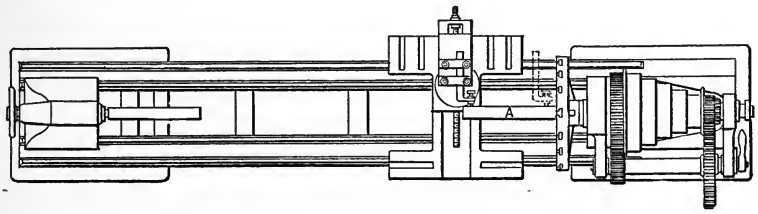


FIG. 204. — Plan of Lathe being Tested for Alignment of Head-Stock and Tail-Stock Spindles.

The vertical alignment of the tail spindle is tested in the same manner, as shown in Fig. 203. It may also be tested by bringing the pointer down on the spindle itself, when it is run back into the tail-stock, and again when it is run out as far as it will go. It sometimes happens that we shall get a different result by sliding the tail-stock to a different position on the bed. In this case we will probably find some inequality in the V's to account for it.

To test the lateral alignment of the head spindle, a bar of the size of the ordinary lathe tool, with its front end bent to a right angle, and provided with a micrometer head, is placed in the compound rest as shown in Fig. 204, and the reading made in a manner similar to the last test. The lateral alignment of the tail spindle is tested in a similar manner, moving the carriage to the desired point.

To ascertain the accuracy of the center hole in the head spindle, we may use our micrometer at the end of the test bar A, as shown in Fig. 204, and by turning the spindle a quarter of a turn at each reading we may ascertain its accuracy with certainty.

The foregoing tests would seem to be sufficient to insure the correct boring of a job on this lathe. But it must not be forgotten that the error detected by the test, as shown in Fig. 204, will be doubled in boring a piece of work.

Therefore the best test of ascertaining the boring quality of the lathe will be by bolting a cast iron test piece to the face-plate, as shown in Fig. 205. A very light cut is taken off from the raised portions C, C, and measurements taken with the micrometer. This test for boring will be much more conclusive than attempting to actually bore a piece of work, owing to the difficulty of making any boring tool, held in a compound rest, bore the same sized hole as both ends of a piece from 12 to 30 inches long. In this connection a diagram and all necessary dimensions for test pieces for different sized lathes are given in Fig. 207.

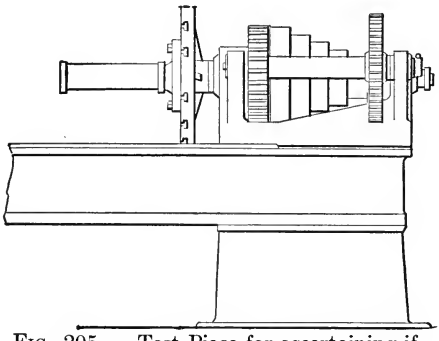


FIG. 205. — Test Piece for ascertaining if Head-Stock Spindle is Parallel with the V's.

To test for the concavity or the convexity of the face-plate it is usual to use an ordinary straight-edge and three slips of paper. This may be nearly correct, but we have no means of knowing the exact amount of the error. For this reason the micrometer straight-edge shown in Fig. 206 was designed. The stock A is slotted at each end, and in these slots are secured the outer points B, B, ca-

pable of being adjusted to different diameters of face-plates, and are secured by the thumb-nuts C, C. The center point D is a micrometer head, operated by the usual milled head E.

In using this straight-edge it is first turned up on a fixed straight-edge and the center point adjusted so that the three points are accurately in line, using slips of paper to ascertain this correctly. The test bar is now placed in the head center hole and the flat space *a* of the straight-edge laid upon it for support.

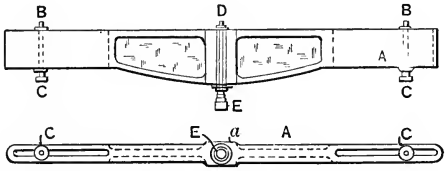
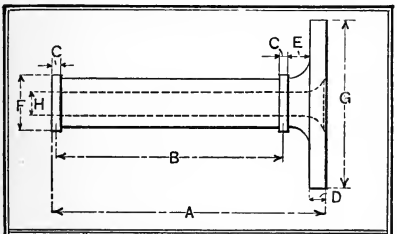


FIG. 206. — Micrometer Straight-Edge for Testing Face-Plates.

Slips of paper are now introduced between the points and the face-plate. The micrometer position is noted, and then adjusted to hold the center slip of paper, when a second reading will give convexity or concavity of the face-plate.



Swing of Lathes	A	B	C	D	E	F	G	H
14″ and 16″	14½	12	1/2	1	1	3	9	1½
18″ and 20″	17⅝	15	½	1⅛	1	3¼	11	1¾
22″ and 24″	21⅛	18	⅝	1¼	1¼	4	13	2
26″ and 28″	24⅛	21	⅝	1⅜	1¼	5	15	2¾
32″ and 36″	27¾	24	¾	1½	1½	6	17	3½
42″ and 48″	31¼	27	¾	1¾	1½	7	19	4
60″ and 72″	35	30	1	2	2	8	21	4½

FIG. 207. — Table giving Form and Dimensions for Test Pieces shown in Fig. 205.

The allowable limits of variation of lathes may be about as follows, viz.: 14 to 20-inch swing lathes, inclusive, .0005 inch; 22 to 28-inch swing lathes, inclusive, .001 inch; 30 to 48-inch swing lathes, inclusive, .002 inch; lathes larger than these, .003 inch.

These limits apply to all the foregoing tests, the distances between testing points to be as given in the table, Fig. 207. It should be understood that no convexity of a face-plate is to be allowed.

The various other points of inspection as given in the report blank will need no special explanation, certainly not to men accustomed to this class of ofttimes trying and delicate work.

INSPECTION REPORT ON LATHE

NAME OF COMPANY

Inspection No.....Date, inspection commenced .....
Size of Lathe.....Date, inspection completed .....
Lathe prepared for inspection by .....
Special features of Lathe.....
.....

1. Level longitudinally.....	20. Center hole in head spindle .....
2. Level laterally.....	21. Back gears, run .....
3. Swing over the V's	22. Second back gears, run .....
4. Swing over the carriage	23. Internal gear, runs.....
5. Distance between centers.....	24. Feed gears on head, run .....
6. Fitting of head-stock on V's.....	25. Compound rest bevel gears, run .
7. Fitting of tail-stock on V's.....	26. Apron gears, run .....
8. Fitting of carriage on V's.....	27. Rack pinion works.....
9. Bores, large at inner end.....	28. Lost motion in apron gears .....
10. Bores, large at outer end.....	29. Reverse device in apron.....
11. Faces.....concave.....	.....
12. Head center, high at outer point.	30. Lead screw.....
13. Head center, low at outer point .	31. Tail spindle screw fits.....
14. Head center, to the front at outer point	32. Cross feed screw fits .....
	33. Comp. rest screw fits.....
15. Head center, to the rear at outer point	34. Appearance of scraped surfaces..
	35. Appearance of polished surfaces .
16. Tail center, high at outer point..	36. Finished corners properly rounded
17. Tail center, low at outer point...	37. Width on cone steps .....
18. Tail center, to the front, at outer point	38. Change-gears fit studs properly.
	39. Wrenches fit properly.....
19. Tail center, to the rear at outer point	40. Squares for wrenches of uniform sizes.....

Remarks .....
.....
.....
.....

Signed.....
Inspector,

A critical examination of the above list of questions is invited in order to fully appreciate the value of such a thorough system of tests both to the concern who builds the lathe and to he who purchases and uses it. Such a system will give a healthy tone to the workmanship of the shop, and when fairly met by the conditions of the machines turned out will be a source of pride to the workmen employed in it.

On the other hand it will give a feeling of confidence and security to the purchaser, who will naturally feel that he is getting full value for the money he has spent in purchasing the machine. Further, the lathe going into the shop with such prestige will naturally be looked upon as a good machine, and more than the usual amount of care will be bestowed upon it and upon the product which it turns out.

CHAPTER XIII

LATHE WORK

The use of hand tools. Simple lathe work. Lathe centers. Care in reaming center holes. Locating the center. Use of the center square. Angle of centers. Lubrication of centers. Centering large pieces of work. Driving the work. Lathe dogs. The clamp dog. The die dog. The two-tailed dog. Lathe drivers. Using dogs on finished work. Clamp dog for taper work. Bolt dog. Methods of holding work that cannot be centered. Center rest work. Chuck work. Use of face-plate jaws. Lathe chucks. The Horton chuck. The Sweetland chuck. The Universal chuck. Face-plate jaws. A Horton four-jaw chuck. The Horton two-jaw chuck. A Cushman two-jaw chuck. Chucking cylindrical work. Inside chucking. Chucking. Chucking work supported in a center rest. Pipe centers. Mortimer Parker's improved forms of pipe centers. Spider centers. Ball-thrust pipe centers. Lathe arbors or mandrels. Kinds of mandrels. Expanding arbors or mandrels. Making solid arbors. The taper of an arbor. Hardened and ground arbors. The Greenard arbor press. Its advantages.

In the chapter on lathe tools the subject of hand tools was purposely omitted, as their use has greatly diminished during the past few years, with the possible exception of their employment on small bench lathe work and on some kinds of brass work, and much of the work formerly done with hand tools is now done in the regular operations on the turret lathe, the screw machine, and with forming tools on ordinary engine lathes.

Such hand tools as are still used in a limited degree will be referred to in the proper places in the following description of lathe work.

When the apprentice is first put to work on a lathe it will probably be the turning of a piece of shafting on centers, and his first duty will be to center it, that is, to drill and ream proper bearings for the center. If he is in a modern shop the old method of form-

ing the center hole by means of a prick-punch and a hammer will not be tolerated. Neither will the practice which succeeded it, that of drilling a small hole and then spreading it out or countersinking it with the center punch. The hole was once drilled with a "fiddle-bow drill," which was later replaced by the geared breast drill, which is very convenient for some jobs but not a tool to drill a good center hole with.

Lathe centers should be accurately ground to an angle, at the point, of 60 degrees. Center grinding attachments are provided for this work (as shown in the chapter on lathe attachments),

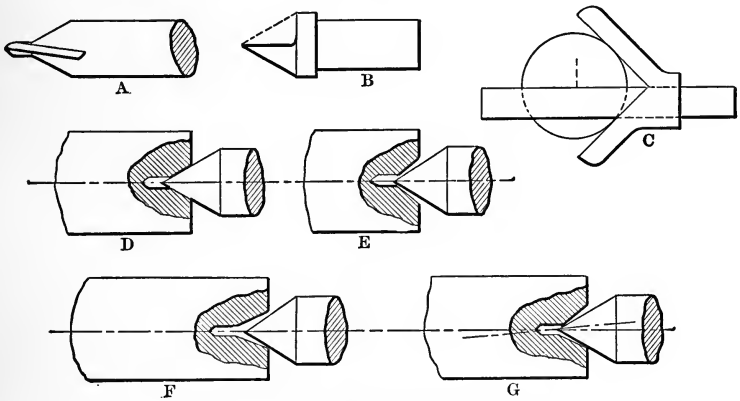


Fig. 208. — Centering Lathe Work.

which will give a very perfect angle. Of course the center has been previously hardened so as to stand the wear of the revolving piece of work. Nevertheless there should be considerable care exercised in drilling and reaming the center hole so that it shall really fit the angle of the center. There are various ways of doing this. The most convenient way is to use for this purpose a combined drill and countersink shown at A in Fig. 208, which will drill the center hole and countersink or ream it to the proper angle. These are made of various sizes to adapt them to the diameter and weight of the work to be centered. At B is shown another and older form of center reamer which is made by turning up the tool to the proper angle and then cutting away the upper half so as to give a cutting edge.

The disadvantage of using this form is that two operations must

be performed, that of drilling, and afterwards reaming or countersinking.

To center a piece of round material it may be first "scribed" by the dividers or the hermaphrodite calipers (a caliper having one regular caliper leg and one pointed one, similar to the leg of dividers), which are set approximately to the radius of the piece, and three or four arcs marked across the previously chalked surface, forming a small triangle or a square, within which the first prick-punch mark is made. This is followed by the drilling.

This may be more quickly done by a center square shown at C, Fig. 208, applying it as shown and scratching a line across the work, then turning the work about a quarter turn and scratching again in the same way. The intersection of these lines will be the center, which may then be marked with the prick-punch as before.

The use of a centering machine will much facilitate the work on small and medium sized work. In this machine the work is held in a self-centering chuck, mounted on a short lathe bed and holding the piece of work exactly in line with and in front of the center drill and countersink shown at A, and held in a chuck carried by the spindle of the machine which has a head-stock quite like that of an ordinary lathe, and the spindle adapted to slide forward in drilling the hole. By the use of this machine the center drilling and countersinking will be in accurate alignment with the axis of the work, and with this drill the angles will be correct, the work and the center appearing as shown at D, in the above engraving.

Should the form of a center reamer, or countersink, be too obtuse an angle the effect will be as seen at E, in which it is seen that the center bears only slightly near its point. It will thus be worn out of shape and quite naturally the axis of revolution will change.

If the angle of the center hole is too acute the lathe center will only bear at the edge of the hole, as shown at F, and the tendency will be to wear a crease around the center at this point, and the work will finally "run out," that is, the axis of revolution will change as in the last example.

Should the drill and countersink not be in line with the axis of the work the result will be as shown at G, and the work will not only run out of true in a little time, but the lathe center is likely to be spoiled.

The proper lubrication of tail centers is important, otherwise the pressure will create so much friction that the center will heat and "burn off." To prevent this some centers, particularly large ones, have an oil hole drilled in the point, which is left large enough for that purpose. This hole connects with one at right angles with it and opening beyond or outside of the end of the work, and through which oil may be introduced while the lathe is running, thus keeping the center always well lubricated. The plan is an excellent one on heavy work, or in fact on nearly all work in lathes of 24-inch swing and larger, and the larger the center the more benefit will be found in its application.

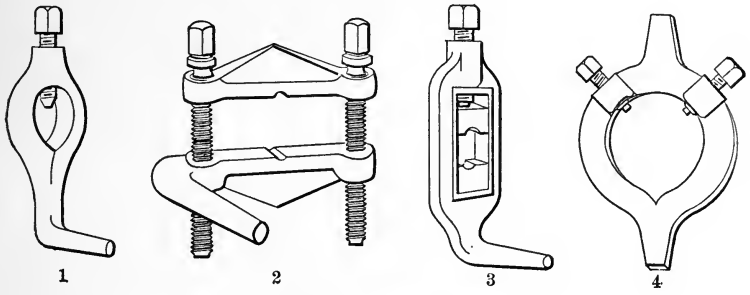


Fig. 209. — Lathe Dogs.

From these examples and remarks it will be seen that much depends on making the center holes of the right form if we expect to produce a good piece of turned work.

In centering large pieces of work it is sometimes the custom to hold one end of the shaft or forging in a chuck on the main spindle of the lathe, and the other end in a steady rest, or center rest. The lathe is started and a pointed tool set in the tool-post is brought against the work and the center scratched into it as it revolves. This is quicker and more accurate than the scribing method, particularly in the case of heavy and rough forgings.

The piece of work having been properly centered, we apply to it a dog which serves to drive it and suspend it between the centers, first carefully oiling the tail-stock center and setting it up just tight enough to hold the work closely and without end motion.

Lathe dogs are of various kinds. The most common kind is that shown at 1, in Fig. 209, which is fixed to the piece to be turned

by the set-screw and the work is driven by the tail of the dog entering the driving slot in the small face-plate of the lathe. The clamp dog shown at 2 is useful for driving square or flat pieces, and is also frequently used for cylindrical work, which it is not so liable to mar as is the set-screw of the first form.

At 3 is shown another form known as a die dog, the jaws being movable and closed up by the set-screw. The jaws being threaded may be applied to threaded work which is of such form that a dog cannot be placed upon any part but that which is threaded.

At 4 is shown what is called a two-tailed dog, sometimes used on large work and driven from "drivers" placed against the two tails. These drivers may be made for the purpose and consist of a piece of round steel of sufficient length to reach from the front of the face-plate out to and across the dog, and be secured to the face-plate by a cap screw, with a washer under its head, and coming through the face-plate from the back and into the end of the driver. Or it may have a shoulder and be held by a nut.

More often, however, the driver is a bolt long enough for the purpose, with a sleeve made of a piece of gas pipe or a block of cast iron with a hole through it, which keeps the end of the bolt far enough to reach the dog.

In placing dogs on finished work a piece of brass or copper should be put under the points of the set-screws to prevent marring the work. In using the clamp dog at 2 on finished work the pieces of brass or copper should also be used.

Various other forms of dogs are used for special work and for very large work; as, for instance, two more or less curved bars and fastened together by bolts, somewhat in the form shown at 2, Fig. 209.

But in all cases the principle is the same, to clamp to the piece of work a device having formed upon it a projecting part, called the tail, by which the work may be rotated.

In some cases when the clamp dog shown at 2 is much used on taper work the heads of the clamp screws are made in the form of eyes, and the upper cross bar or clamp bar has trunnions or bearings turned on each end which enter into the holes or eyes of the bolts. By this means the clamp bar may turn in its bearings sufficiently to have its flat side set fairly on the inclined surface of the taper.

In driving bolts which are to be threaded and in which the marks of the center hole in the top of the head are not objectionable, a "bolt dog" is used. This is simply an offset plate fastened to the face-plate by a single bolt and its free end slotted so as to embrace the head of the bolt. This device is not much used at the present time as bolts and cap screws are usually made from a bar in the turret lathe at much less cost than is possible to produce them in an engine lathe.

Lathe work that is not held suspended between centers must be held by one of the following methods, namely: bolted or clamped to the face-plate; held entirely in a chuck; one end held in a chuck and the other in a center rest; or secured to the carriage, or some part of it, as in boring jobs. One exception is made to these statements. This is that work *may* be held against the head spindle center by any convenient means, and the other end supported in a center rest. This is usually only resorted to for such work as boring and reaming and, with the exception of the advantage derived from accurate centering by means of the head spindle center, is not a very advisable method of running work in a lathe, particularly when a chuck with truly concentric jaws is at hand.

What is ordinarily called center rest work is all kinds in which one end is supported in a center rest. Of course this does not include work held on centers and supported in the center or at any intermediate point by a center rest. In this case many machinists call it a "steady rest," rather than a center rest, and this function may be readily performed by a back rest or what is called by some manufacturers a steady rest, which has the three jaws of the center rest, although they are not placed equidistant around the circle and the supporting casting is left open in front instead of being provided with a hinged top segment.

Chuck work and face-plate work is very closely allied, and in fact very many face-plate jobs can readily be done in a chuck, and nearly all chuck jobs can be done if fixed to the face-plate in the usual manner. It is altogether probable that the first chuck made was simply a face-plate provided with jaws temporarily attached, and it is more than likely that these "jaws" consisted merely of blocks or studs fastened to the face-plate and provided with set-screws for holding the work.

One of the oldest chuck manufacturers was E. Horton, who established the business in 1851. One of the Horton three-jaw chucks is shown in Fig. 210.

At A is shown a face view of the finished chuck. It consists of a front and a back plate shown respectively at D and B. The jaws are moved in and out simultaneously, by means of the geared steel screws, the small bevel pinion formed on them engaging the circular steel rack C, which is enclosed in a deep groove or recess in the back plate B, as shown. At D is shown the front plate with the jaws in place, with the projecting portion at the back tapped to receive the steel screws, which are shown in place. The front

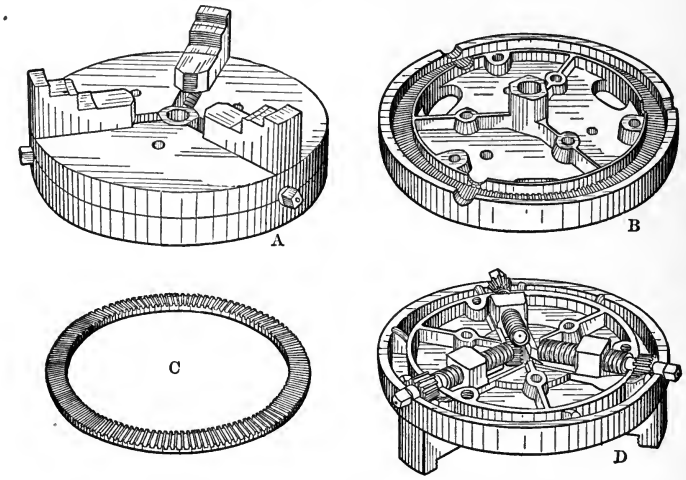


Fig. 210. — The Horton Three-Jaw Chuck.

and back plates fit each other closely, making a perfectly tight casing for the gearing and screws, so that no dirt, chips, etc., can possibly get into them and clog and injure the gearing. The jaws are forged solid, by which great strength is secured to withstand the strain of heavy work.

At A, Fig. 211, is shown a Sweetland chuck, which in a general way is similar to the Horton chuck, but possesses some advantages, in that it may be used as a "universal" chuck, so called, in which all the jaws move simultaneously to or from the center, or it may be readily changed so that the jaws work independently of each other, thus adapting it to a large variety of irregular and eccentric work.

The design of the improvement is to make the chuck independent as well as universal, thus combining two chucks in one. In the recess underneath the rack are the cam blocks, beveled to correspond with the level recess in the rack. The cam blocks are held in place by the convex spring washers, which allow them to be moved to or from the center without disturbing the nuts, the friction being sufficient to hold them in place. When moved to the outer portion of the rack they connect the gearing, making the chuck universal, and when moved inward they disconnect the gearing, thus making each screw independent.

The advantage of making each screw independent, without disconnecting the others from the gearing, is a feature not combined in any other chuck, and is an improvment fully appreciated by the

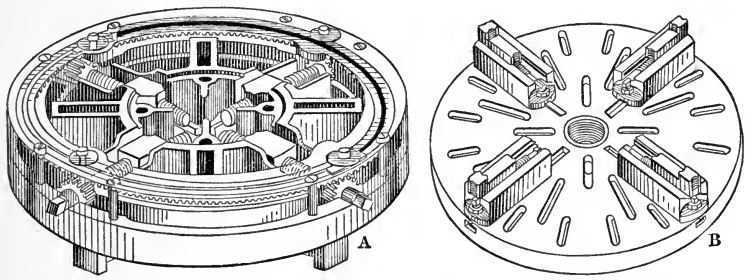


FIG. 211. — Sweetland Four-Jaw Chuck, and Cushman Face-Plate Jaws.

mechanic when adjusting the jaws for eccentric, concentric, or universal work. For instance, the chuck having been used independent, the workman wishes to change to universal, the jaws are moved inward until the outer end is true with the line on face of chuck; now each screw can be engaged with the rack separately by sliding the cam block outward. If one jaw is found to be out of true it can be disconnected and reset, leaving the others in mesh undisturbed.

This chuck has a large hole in center, and will allow a drill or reamer to pass through work without injury to face of chuck.

The jaws, rack, and pinion screws are made from forged steel, and all wearing parts properly tempered.

The "bites" on the jaws are ground true after being hardened and tested thoroughly before coming out of the grinding machine.

At Fig. 211 are shown the face-plate jaws heretofore referred to, and which, when attached to a face-plate, make a very serviceable and practical substitute for a chuck, and advisable to have from questions of economy, even on lathes as small as 30-inch swing, while on lathes above 40-inch swing they are all the more useful, and on 50-inch swing and larger are almost indispensable, as the largest chucks usually made are 42-inch and these are very heavy and very expensive, while a set of four jaws for the face-plate may be had at a comparatively nominal cost.

Figure 212 shows three forms of chucks. At A is a Horton

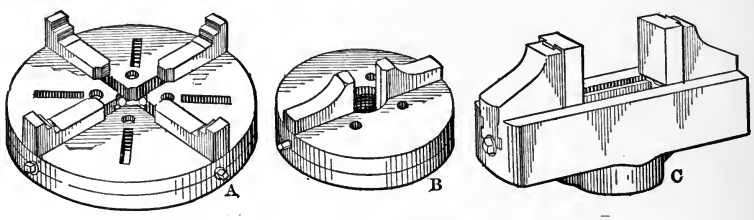


Fig. 212. — Horton and Cushman Chucks.

chuck with four jaws. It is built on the same plan as the three-jaw chuck shown in Fig. 210.

At B is shown a Horton chuck with two jaws, which is very useful for certain classes of work, and better adapted than those of three or four jaws.

Not only the Horton chucks but also those of other makers are built with two, three, four or six jaws, as the nature of the work may demand.

At C is shown a Cushman two-jaw chuck, with provision for slip, or "false jaws." By this construction special jaws may be made with faces of such contour as to fit the irregular form of the pieces to be machined. This form of chuck is used for the machining of valve bodies and similar work, and is sometimes fitted with various indexing devices by means of which the piece may be turned from side to side and held while various operations are performed.

Special chucks are made of various forms and with a varying number of jaws, of a variety of different shapes, all of which are too numerous to illustrate or describe here.

In chucking cylindrical work with a universal chuck of three

jaws the work is correctly centered by the chuck jaws, provided there are no uneven places on the work, which by coming under either of the jaws tend to throw it out of true. Such work is usually that of boring, reaming, or facing, and similar work on the face or inside of the casting or forging, and such part of the outside as extends beyond the chuck jaws.

It should not be forgotten that while we usually grip work upon the *outside*, the chuck jaws work equally well by bearing against the *inside* of the work; for instance, the inside of the rim of a gear that is to be faced, bored, and reamed.

When round rods or bars are to be machined or pieces cut from them, whether to be partly machined or not, a drill chuck, so called, is used. This is a two-jaw chuck, the jaws being of a variety of forms, from the shape shown in Fig. 212 to V-shaped jaws with interlocking teeth, the design of all of them being to hold the bar or drill firmly, with as little force applied to the right and left screw that operates them as possible.

Work may be such that one end is held in the chuck and the other supported by the tail-stock center, or by a center rest whose jaws furnish a three-point bearing for the cylindrical surface of the work. While the method of supporting the work by the tail-stock center is used for work that is to be *turned*, the second method, that of supporting the work in a center rest, is better adapted for *drilling* and *reaming* operations. These operations may be wholly done with the drill and reamer, or by the use of an inside boring tool held in the tool-post of the compound rest.

It is a common job to have to face up the flanges on the ends of pipe of various sizes. Sometimes these pipes are of wrought iron or steel with the flanges screwed on. Sometimes they are cast upon cast iron pipe. The ordinary method is to hold one end in a chuck and the other end on a "pipe center," of one form or another. One form of these centers is called a "spider center," and often consists of any convenient casting, circular in form, that comes handy. With several set-screws tapped radially into its edges and adapted to be backed out against the inside of the pipe and firmly held, while a drilled and countersunk hole in the center affords a good bearing for the lathe center. Mr. Mortimer Parker suggests some improved forms which are shown in Fig. 213, in which A shows a

new spider center which is quite different from the old style B that requires, as shown, a block of wood against it to keep it from shoving in or twisting sideways when the center is pressed against it, or when a heavy cut is started.

This improved center will stand a heavier cut and can be set quicker than the other style. If the outside is turned true with the hole the job can be set very readily. C, D, and E show end views of different forms of this center; and F, G, and H are different sizes with bronze bushings in the interior.

At I is illustrated the manner in which a common cone center

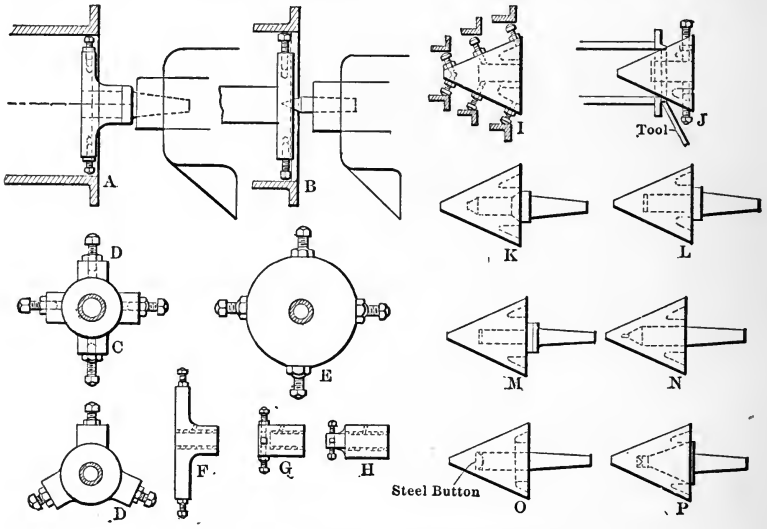


Fig. 213. — Pipe Centers and Spiders.

can be turned into a spider center by drilling three rows of holes and putting in set-screws and jam-nuts, only one set of screws being needed, as they can be used in either series of holes.

A spider center allows room for the tool to clear when facing off the end of a flange, but a cone center does not. When the tool gets down to the center, as at J, it leaves a shoulder which must be turned off with a pointed tool.

K is a center with a cone bearing at each end of the hole, which keeps free from play even if it does wear. Center L is less work to make, but does not turn around when a heavy cut is taken; hence a ball-thrust bearing should be used as at M for heavy work.

Center N works well in a heavy cut and is easily made. Center O is less work to make than any of the others and also works well with heavy work.

In facing up pipe flanges it is sometimes the practice to hold one end in the chuck and support the other end in a center rest. The disadvantage of this method is that the roughness of the outside of the pipe is a very poor bearing for the center rest jaws and poor work in facing is likely to result, while the same pipe carried on a pipe center, in the same lathe, will be a creditable job.

Lathe arbors are an important adjunct to lathe work. They are commonly called arbors although the old English name of mandrel is the proper word, as an arbor is properly a carrier for a tool, as a saw arbor, a milling machine arbor, etc., while a mandrel is used for carrying a piece of work to be turned.

Mandrels are of two kinds, solid and expanding. The solid mandrel should be made of hard machine steel or a cheap grade of cast steel capable of being hardened.

In Figure 214 are shown two forms of arbors. That at A is the

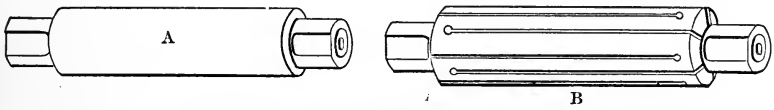


Fig. 214. — Lathe Mandrels or Arbors.

common form. The ends are turned down somewhat smaller than the central body, and on one side, at each end, is a flat space for the set-screw of the lathe dog to rest upon. The ends are slightly recessed around the center hole so that it will not be bruised if the end is struck with a hammer. The central body should be ground with a very slight taper. The entire piece should be hardened, not simply the ends, as formerly. A $\frac{1}{4}$-inch arbor should be $3\frac{1}{2}$ inches long and a 4-inch arbor 18 inches, all intermediate sizes being of the same proportion.

At B, Fig. 214, is shown an expanding arbor or mandrel. This is made in two parts, the arbor proper and an outer shell. The inner arbor is turned and ground to a considerable taper and the outer shells accurately fitted to it. It is then split, as shown,

by from eight to twelve cuts, alternately beginning at opposite ends, so that in forcing the inner arbor in on the taper the outer shell is expanded in very nearly a circular form, at least near enough for all practical purposes. At the end of each cut is drilled a small hole to prevent cracking.

A cheap imitation of this really excellent device is made by splitting the outer shell all the way through at one point only, which will do as a makeshift when nothing better can be had.

There are various forms of expanding arbors, some of which have considerable merit and others very little. The one illustrated above will probably be found to give the best satisfaction.

In making solid arbors it should be remembered that they must be turned considerably over size, then hardened, which will change their form somewhat, and then rough ground to nearly the proper size. They should then be laid aside for some time to give the steel an opportunity to take on its final changes and attain a permanent condition as to size, straightness, etc., before it receives its final finish grinding, which should diminish its diameter very slightly.

The drilling in the ends for the center hole and the countersinking should be carefully done, the angles of the sides of the countersunk hole being exactly 60 degrees.

Arbors are hardened for several reasons, principally to make them accurately cylindrical, much stiffer and more rigid, and also less liable to accidental injury, but not to prevent lathe tools from cutting into them when used by a careless workman.

The taper on an arbor is usually about a hundredth of an inch per foot with the center of the arbor of the standard diameter. The fact that the arbor is tapered to this extent makes it necessary to be careful to force the arbor into the reamed hole from the same side that the reamer has entered, which should also be the same side first entered by the piece that is to fit in the hole, provided it is to be a close fit. This is frequently marked on the drawing and it should always be so indicated for the guidance of the workman.

Hardened and ground mandrels serve the very excellent purpose of preserving the uniformity of sizes of holes, since if the holes are not truly sized the pieces will either drop on to the arbor too loosely or fail to go on sufficiently for good and convenient work. Again, the arbor being so slightly tapering, the workman will

notice even a small difference in the diameter of the hole by the position of his piece on the arbor, and is likely to report the defect in the work in this respect.

The use of expanding arbors has not these advantages as they are ground perfectly straight. But they are to be preferred for this very reason when running fits are desired.

Arbors should not be *driven* into reamed holes with a hammer. An arbor press should be used and the author knows of none better than the Greenard press, which is made in various sizes, from the small one to fasten to the tail end of the lathe bed to the largest sizes which have a broad floor base. One of the former is shown in Fig. 215. By the use of these presses there is no shock in forcing an arbor into the work, and therefore neither the arbor nor the work is injured. In addition to this advantage, the arbor maintains a perfect alignment with the hole as it is forced in, and therefore there is no unequal strain or distortion.

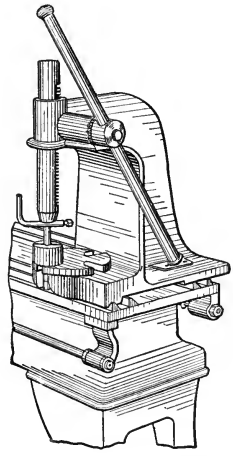


Fig. 215 A. — Greenard's Arbor Press.

The rack and pinion arrangement of this arbor press is at once simple and effective, and the rotating table with its various sized recesses in the edge furnishes an excellent bed for supporting the work as the arbor is forced into it. A more convenient arrangement could scarcely be imagined for this work.

CHAPTER XIV

LATHE WORK CONTINUED

Irregular lathe work. Clamping work to the face-plate. Danger of distorting the work. A notable instance of improper holding of face-plate work. The turning of tapers. Setting over the tail-stock center. Calculating the amount of taper. Taper attachments. Graduations on taper attachments. Disadvantages of taper attachments. Fitting tapers to taper holes. Taper-turning lathes. Turning crank-shafts. Counterbalancing the work. Angle plate for holding the crank-shaft. Forming work. Forming lathes. Drilling work on the lathe. Chuck and face-plate drilling. Holding work on the carriage. Boring a cylinder. The author's design for boring large cylinders. Holding work by an angle-plate on the face-plate. Thread cutting. Calculations for change-gears. Reverse gears. Arrangement of the change-gears. Ratio of change-gears equal to ratio of lead screw to the thread to be cut. Cutting left-hand threads. Compound gearing. Calculating compound gears. Cutting double threads. Triple and quadruple threads. Boring bars. Varieties of boring bars. Driving boring bars. Boring large and deep holes. The author's device. The drill, boring bar and cutters for the work. Flat cutters for boring holes. Boring bar heads or arms. Hollow boring bars. Milling work on a lathe. Milling and gear cutting on a speed lathe. Grinding in a lathe. Cam cutting on a lathe. Many uses for the engine lathe.

THERE is so much irregular work constantly done on the lathe that no specific description of it can be given. It is the unknown quantity that the machinist has to deal with and he is expected to be equal to the occasion and so fertile of resources as to be ready with a proper method for doing every job that turns up, that he will not be obliged to hesitate long for means to accomplish the end sought.

Much of what may properly be called irregular work will be such as can be handled on the face-plate or in an independent jaw chuck. Yet these appliances for holding the work will frequently

have to be supplemented by the tail-stock center, the center rest, and the follow rest, as well as the taper attachment.

In clamping work on the face-plate there is danger of springing the work as it is fastened down. The result will be that it is held in a distorted position while being machined, and upon being released by the bolts of other clamping devices it will spring back to its original position and so show distorted machining. For this reason much care should be exercised to see that it rests fairly on the face-plate immediately under the clamps or bolts that hold it down.

The same idea applies to rings or similar shapes when held in the jaws of a chuck or in face-plate jaws. There is always the possibility of springing them out of shape and that this forcing process will show in distorted work when the piece is taken out of the lathe. The author once saw rings of cast iron two inches thick, 6 inches wide, and about 30 inches inside diameter, pressed out of shape

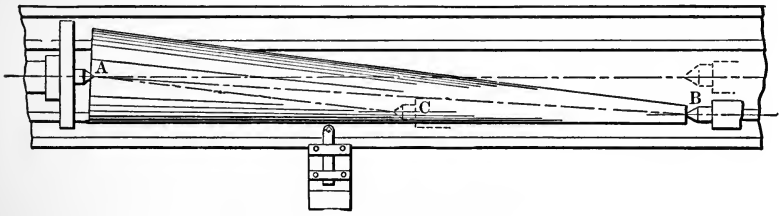


FIG. 215 B. — Turning Tapers.

by the face-plate jaws attached to a 60-inch face-plate, so much that several of them were spoiled, and the expedient of strapping them to the face-plate had to be resorted to in order to produce work as true as the job called for.

Work may also be distorted when carried in a steady rest, a back rest or a center rest, by this attachment having been set out of line, either too high, too low, or to one side. Much more care is needed in adjusting these attachments than they sometimes receive.

The turning of tapers may be classed as irregular turning work. If they are slight the tail-stock center may be set over sufficiently to give the required inclination, particularly if the work is long. When the taper is considerable, it will not be proper to set the tail-stock center over for this purpose as it throws the head-stock and tail-stock centers too much out of alignment to work properly. This is shown in Fig. 215. One half the taper shown, on this length

of work would be practical. In this engraving A is the head center and B the tail center.

It will be noticed, however, that if the work is but half as long and the tail-stock center located at C, the inclination will be twice as great and consequently the error in the alignment of the centers double what it would be with the tail-stock center located at B, and the case more impractical than at first.

The tail-stock is arranged so that the center may be set over to the rear as well as the front, so that the small end of the taper may be toward the head-stock when such a position is more convenient.

In setting over the tail-stock center it must be borne in mind that the difference in diameter between the large and the small end will be twice the distance which the center is moved from the center line of the lathe. Therefore, if the work is two feet long, and we want a taper of one inch in two feet, or half inch per foot, we set the tail spindle over half an inch. The amount set over at the tail-stock gives double that taper in the whole length of the work.

Consequently, if we *divide the amount of taper* on the entire length of the work *by the number of feet in length, we get the taper per foot.* If this simple rule is remembered the mistakes that often occur in turning tapers will be avoided.

In all taper turning, however, it will not be sufficiently accurate to measure the amount of tail-stock set over, but the work must be carefully calipered as the turning process goes on.

When the taper is considerable, it is better to do the work in a lathe having a taper-turning attachment. Examples of this device will be found in the chapter on lathe attachments, where it will be seen that the travel of the compound rest in a transverse direction is governed by a swiveling bar which may be set at any desired inclination with the V's of the lathe.

While there are usually graduations on the end of the taper attachment that are intended as a guide in setting the swivel-bar or guide, they are frequently misunderstood and consequently useless. Usually they are marked for so much taper per foot, and when so designated the length of the work in feet must be considered, if the diameters at the large and small ends are given on the drawing.

If the taper slide or guide-bar is graduated in degrees, the case is nearly hopeless with the usual machinist, as the graduations are

of no benefit whatever to him, as his drawing will very seldom be dimensioned in this manner, but rather the extreme diameters given, or the taper will be so much per foot.

The use of the taper attachment permits a much wider range of tapers to be turned than can be successfully accomplished by means of the set-over feature of the tail-stock. And we have the great additional advantage of always keeping the centers in line, so that accurate work can be done, which is not always the case when the tail-stock is set over, except for very slight tapers.

One of the drawbacks to the use of taper attachments is that a certain amount of back-lash is liable to exist when many parts are necessary to the design of the mechanism, from the guide-bar or swivel-bar to the point of the cutting-tool. These will give a certain amount of difficulty in making a straight, smooth cut. Consequently, the gibs should be set up as close as practicable, all nuts and adjusting screws set up tight and as much vibration and back-lash eliminated as possible, and then the back-lash be taken up by hand before the tool begins to cut.

In all taper turning it is necessary that the point of the tool be set at exactly the height of the points of the centers, otherwise a true taper will not be the result but will be slightly concave rather than in a straight line.

In all cases, in turning tapers to fit a tapering hole, the exact amount of *taper* should first be obtained so as to fit the tapering hole, but to be considerably larger than its final size. Then the *diameter* is turned correct, the calipering being usually done at the small end.

Taper-turning lathes are sometimes made in which the head-stock and tail-stock are mounted upon a separate bed which is pivoted at the center so that it practically amounts to the lathe swiveling while the tool carriage runs straight. In this lathe the centers are, of course, always in line, the setting for the required result is quickly done, and as the whole mechanism may be of very rigid construction, the work done on it is very accurate as well as economical. The turning of crank-shafts is a frequent trouble to the inexperienced man who has this work to do. In the present case it is assumed that the crank-shaft has been properly "laid off" with a surface gage, on the surface-plate or table, and the centers

located, drilled, and reamed, and the shaft proper roughed out to nearly its finished dimensions.

The operation to be performed is to turn the wrist-pin. This is shown in Fig. 216. At A is shown the usual method of rigging up for the job. The shaft is placed in V-blocks on the surface table and the wrist-pin blocked up to the proper height, as shown by the surface gage, so that there will be stock enough left on all sides to finish up to the given dimensions. The "offsets" or "throws," C, C, are now put on and the centers accurately located by the

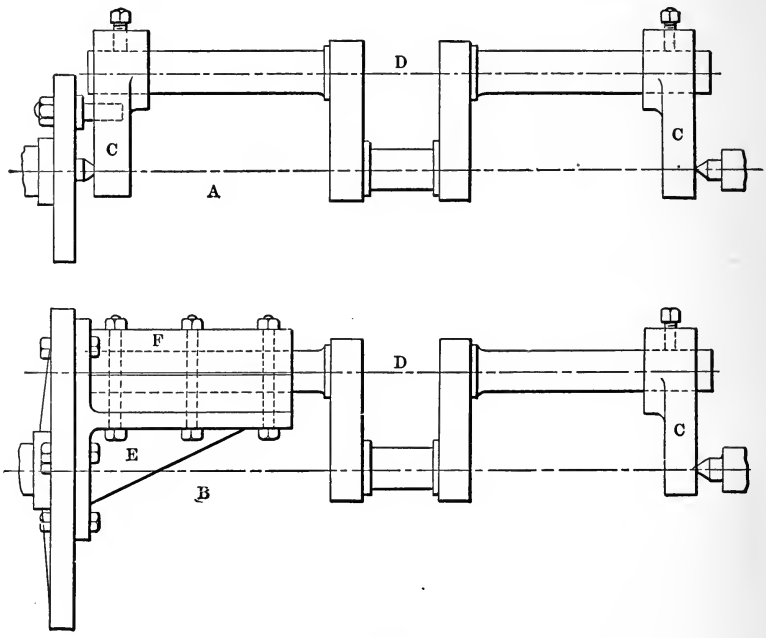


Fig. 216. — Turning Crank-Shafts.

surface gage before the set-screws are screwed up tightly to hold them in place.

The centers are now measured all around with the surface gage once more, to make sure that all are in the same plane. The crank-shaft is now placed in the lathe, the centers in the offsets being used as they are directly in line with the wrist-pin center. A tool long enough to reach down between the arms of the crank must be used. It should be made with a very narrow point, be kept very

sharp, and set either on the center or but a trifle above it. The idea is to avoid as much as possible any undue strain in the turning, as the work will not be very rigid and the cuts taken must be light. The wrist-pin being turned and finished, the offset pieces C, C, are removed, a block fitted in the space D, between the arms of the crank, and it is placed on the shaft centers and finished as any other shaft would be.

One of the precautions that should be taken is to have the work properly counterbalanced by adding on the face-plate the proper weight, opposite the crank when turning the shaft, and opposite the shaft when turning the wrist-pin, so as to prevent undue strain and vibration.

Another and more rigid arrangement is shown at B, in Fig. 216, in which, in place of an offset piece at the face-plate end, the bracket or angle-plate E is used. This is bolted to the face-plate and has a cap F fitted to it and bolted firmly, with the joint held slightly apart with paper or thin cardboard. It is then bored out the exact diameter of the end of the crank-shaft, which is firmly gripped in it and the shaft much more rigidly held than in the former example. The offset piece C is used at the tail-stock center the same as before.

In all these operations great care should be used to lay out all the centers in the same plane, and to locate the offset arms in the same manner. The free and careful use of the surface gage will be necessary to success.

Forming work has been described in another part of this book, and the reader interested in this class of work is referred to the chapters in which these matters are considered. The particular points to be observed in forming work are: to hold the work very rigid; to have a very rigid cutting or tool carriage; to have a tool with a very sharp and carefully "stoned-up" cutting edge; to use a comparatively slow speed and a very fine feed.

When these conditions are obtained the forming lathe works easily, accurately, and efficiently.

The tools must be so formed that by continually grinding on the top the form and contour of the cutting edge is not changed.

The forming lathe may have an automatic feed with a stop which automatically throws out the feed when the proper diameter is

reached. This makes the lathe semi-automatic, in that it need only be set and started, and no further attention given to it until the cut is completed. Thus one man may run a number of machines, and the relative efficiency of each will be reckoned, not so much in the large number of pieces turned out, as in the small cost for labor, which is usually the most expensive item on this and similar classes of work.

This is seen very readily in the automatic screw machine, which turns out much of its work much more slowly than the turret lathe. But the turret lathe requires the constant attendance of a skilled operator, while one man may take care of from four to ten automatic screw machines.

In many respects the engine lathe may be made to take the place of the upright drill, although this class of work is now usually done in the upright drill, the radial drill, or the boring machine. However, there are shops which do not possess all these facilities and still have many jobs that may be properly done in the lathe.

To the ordinary jobs of chucking and reaming it will not be necessary to refer. The same may be said of ordinary drilling such as may be done by holding the work in the chuck and using either a flat drill with a center hole in its rear end for the tail-stock center, and the drill held from turning by a wrench, or similar contrivance.

Drills may be held in the tail-stock spindle, in place of the tail center, if the taper hole is standard as it should be, or when the drill shank is too small a collet may be used. In this way many jobs of chuck or face-plate drilling may be done. When the work is such that it is necessary to revolve the drill instead of the work, the drill may be transferred to the head spindle and the work held by bolting or strapping it to the carriage, the compound rest having been removed for that purpose.

Another method is to strap to the carriage an angle plate, jig, or other fixture suitable for holding the work to be drilled.

There is a wide range of possibilities in this class of work and the ingenious machinist is generally very resourceful in this direction. The following is a case in point;

It is often necessary to bore a hole so large that it is not convenient to do it in the ordinary way, by bolting to the face-plate,

and if the casting has no hole through, or one so small as to require a boring bar too small in diameter to get a steady rest cut, it is almost impossible of accomplishment on the boring machine. The casting shown, marked C in Fig. 217, is of such a nature. The primary factor in the boring of these cylinders is the making of the bracket A, which forms a solid support for the boring bar B. The boring bar B is driven in the usual way, or rather in one of the usual ways. It will be noticed that the taper shank is held from turning by being screwed into the spindle of the lathe head-stock, and that it has a conical bearing at the outer end in the bracket A. The bearing is thus adjustable to take up "back-lash" by sliding the bracket A to the right along the lathe bed, which in this case is of

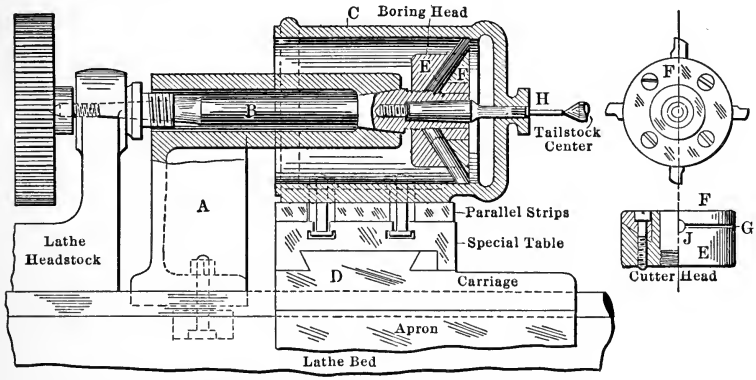


FIG. 217. — Cylinder Boring in the Lathe.

the ordinary English pattern, with a flat bed. Of course, by making the bottom of the bracket to suit the raised V's, the attachment is capable of being made to suit the American style of bed.

The cylinder C is bolted upon a slotted plate attached to the carriage D, upon parallels. In planing the base of the castings, care was taken to make them in all cases of equal distance from the face of the base to the center of the casting — not to the core, as this was liable to be slightly out of true.

Three cutter heads, two roughing and one finishing, were made like the one shown at F, at the right, in Fig. 217. All had four cutters slanting to the left at the inner end, in order to bring the cutting edges outside, or near the end of the block.

At the right of Fig. 217 is shown one of the blocks in detail.

E is turned to the angle at which the cutters were required to be fitted at the point G, and a clamping ring F, turned to fit, was afterwards clamped on by means of four filister head screws. Four holes, as at J, in the small view at the right, were drilled in line with the joint to fit the cutters. After drilling, a small amount was turned off the inner face of the clamping ring F in order that the tools would be clamped when the screws were tightened. This ring when tightened up was found to be sufficient to prevent the cutters slipping in.

To insure the cutters all having an equal cut, the cutting edges were ground and also backed off by means of a cutter bar, mounted on the slide-rest and driven from overhead. The finishing cutter finished from six to a dozen holes at one grinding and it was then a simple matter to set them out a little and regrind. It was found to be advisable to take out and grind the roughing cutters separately on an emery wheel, as working in the sand they wore rapidly. Sometimes one broke in cutting out a projecting lump of metal and they wore generally unevenly.

The hole H, Fig. 217, was bored out (from a cored hole) by two cutters, as shown (roughing and finishing), fluted similarly to rose bits or reamers. The roughing cutter was passed through at the same time as one of the roughing cuts in the large hole; the finishing cut, however, was taken separately to avoid disturbing the large finishing cut. The carriage was fed up mechanically by means of the rod feed.

The device for doing this job, when once made, proved to be useful on other jobs as well.

The author once designed and built a lathe for doing a similar job to the one here described and illustrated, but on a much larger scale. In this case it was required to very rapidly bore and finish large cast iron cylinders about four feet in diameter. As there was ample power to do the work, and sufficient length of bed was allowable to bore a number of these cylinders at a time, and as they were quite short in proportion to their diameter, the lathe was arranged to bore two cylinders at once, with three tools for each cylinder, namely, a roughing tool, a sizing tool, and a finishing tool. Each of these consisted of a cross bar attached to a boring bar, and carrying a cutting tool on each end.

By this arrangement there were twelve cutting tools in action most of the time, and as *two* cylinders were bored during the time of the travel of the tool across *one*, the result was that of *doubling the capacity* of the former machine which did this work.

Another method by which boring work may be done is to attach it to the face-plate of a lathe by the use of an angle-plate, by which means various shaped pieces having a finished surface at right angles to the axis of boring may be conveniently held. Elbows are well handled by this device and many similar jobs will readily suggest themselves to the machinist. And not only boring, but many jobs of turning on such shaped pieces may be conveniently handled by the use of the angle-plate attached to the face-plate of a lathe.

Thread cutting in a modern lathe provided with a quick change gear device for cutting any number of threads per inch, by shifting one or more levers, is a comparatively simple matter. With a lathe equipped with removable change-gears for accomplishing the same purpose it is much more complicated, and its principles frequently misunderstood. Therefore a clear understanding of these principles is necessary to any one who aspires to become an intelligent machinist.

The spindle or head shaft of the lathe runs at the same speed as the main spindle; therefore it takes its place in all calculations for thread cutting. Upon this spindle the first change-gear is placed. The lead screw carries the second change-gear. The ratio of these two gears determines the ratio of the number of revolutions of the main spindle to those of the lead screw. The change-gear placed between this first and second change-gear is an idler gear, since it runs loosely on a stud and serves only to communicate motion, but does not in any way change or modify the ratio.

The reverse gears within the head are used only for reversing the motion of the head shaft, and are also idler gears, not affecting the ratio.

The arrangement is shown in Fig. 218, in which *a* is the head shaft or spindle; *b* is the lead screw, and *c* the adjustable stud in the adjustable stud-plate, segment, quadrant, or sweep, as it is variously termed, marked *d*. A is the first change-gear; B the second change-gear, and C the idler gear. As shown, the two gears A and

B are of equal diameter and number of teeth, consequently the lead screw revolves at the same rate of speed as does the main spindle. It follows, therefore, that if the lead screw is cut with four threads per inch the lathe carriage will move a quarter of an inch with each revolution, and the lathe will cut four threads per inch.

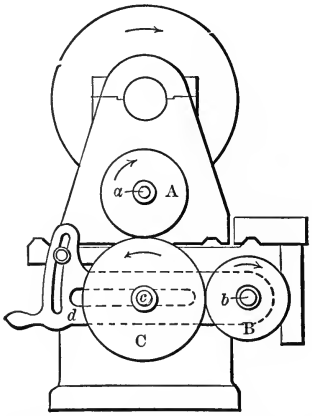


FIG. 218. — Change-Gears for Cutting Right-Hand Threads.

If the change-gear A is only one half the diameter of the change-gear B, the lead screw will revolve only one half as fast as the main spindle, and the lathe will cut eight threads per inch; while if the change-gear B is one half the diameter of the change-gear A, the lead screw will cut two threads per inch.

Therefore, whatever is the ratio of the two change-gears, A and B, to each other, the lead screw will revolve accordingly, and produce a thread of like ratio to the number of threads per inch with which the lead screw is cut. Otherwise, the ratio of the change-gears A and B equals the ratio of the thread of the lead screw to the thread to be cut.

To cut any desired number of threads per inch it is first necessary to find the ratio which the desired number of threads bears to the number of threads on the lead screw; then to select such change-gears as bear this ratio to each other, remembering that if the desired thread is of a coarser pitch than that of the lead screw, the change-gear A must be the larger, and if it be a finer thread than that of the lead screw, the change-gear B must be the larger.

The gears will revolve in direction of the arrows, by which it is seen that the lead screw revolves in the same direction as the change-gear A on the head shaft *a*, and consequently as the main spindle of the lathe. This arrangement, with a right-hand thread (as usual), on the lead screw *b*, will cut right-hand threads.

When it is desired to cut left-hand threads the motion of the lead screw must be reversed. This is done by the addition of the

idle gear E on a second stud *e*, in the stud-plate *d*, as shown in Fig. 219.

When the proper ratio cannot be obtained by the use of the change-gears at hand, or when the gears of the desired numbers of teeth would be too small to properly connect, or too large to be put in place, recourse must be had to what is termed compound gearing. Referring to Fig. 221, and the series of change-gears A, suppose that it is desired to use compound gears, making the ratio 4 to 1. A 36-tooth gear is placed on the head-shaft and a 72-tooth gear on the lead screw. On the idler stud we place two gears, a 48 and 24, fixed to each other by placing them on a splined compounding sleeve which runs loosely on the stud. The 36-gear is engaged with the 48, and the 24 with the 72, as shown in elevation at A, Fig. 220, and more clearly seen at A, in the diagram, Fig. 221.

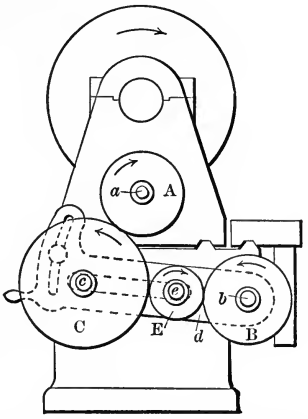


FIG. 219. — Change-Gears for Cutting Left-Hand Threads.

The result of this combination is this: If the 36-gear engaged the 72, the ratio would be 2; and if the 24-gear engaged the 48,

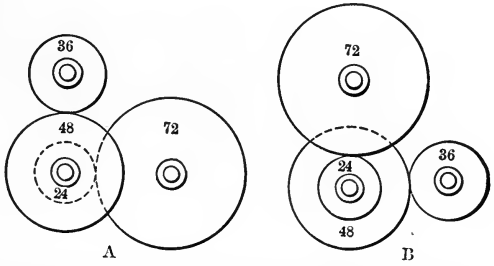


FIG. 220. — Compound Change-Gears for Right and Left-Hand Threads.

the ratio would be 2. These ratios multiplied would be 4. As they are engaged we have 36 to 48, which is a ratio of $1\frac{1}{3}$, and 24 to 72 is a ratio of 3, which multiplied by $1\frac{1}{3}$ produces 4.

The effect, then, of introducing the 24 and 48 gears instead of a

single idle gear is to double the ratio existing between the gear on the head-shaft and the one on the lead screw. The combination as shown would cut 16 threads per inch on a lathe having a lead screw cut with four threads per inch. (Usually lathes will cut this number of threads without compounding. The gears here shown and described are given as a simple example.)

At B, in Figs. 220 and 221, the order of gears is reversed, the

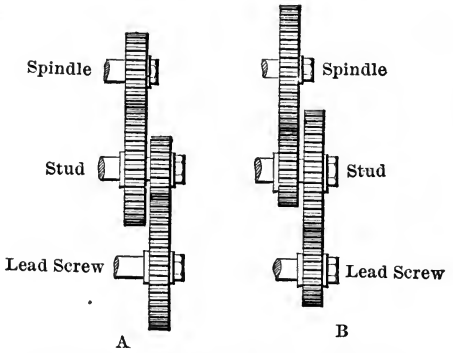


FIG. 221. — Edge View of Compound Change-Gears.

72-gear is placed on the head shaft and the 36-gear on the lead screw. The effect now is, instead of *multiplying* the pitch of the lead screw by 4 ($4 \times 4 = 16$ threads per inch on the work cut), the number of threads of the lead screw is *divided* by 4 ($4 \div 4 = 1$), thus producing in the work a screw of one thread per inch, or one-inch pitch.

By a thorough and correct understanding of these *principles* there should be no difficulty in setting up a lathe for any desired number of threads per inch. It is usual to have compounding gears of a ratio of 2 to 1, as 24 and 48, 36 and 72, and so on. But it may be necessary to use other ratios as $1\frac{1}{2}$ to 1, say 48 and 72, 24 and 36, etc. Or to make the ratio 3 to 1, as 24 and 72, 36 and 108.

It is always advisable to use as large change-gears as possible, as the motion of the lead screw is more regular and steady, and the strain on the gear teeth is less, consequently better work can be done. This should be practised even if compound gears have to be used more frequently.

In cutting double threads the change-gears are set for double the pitch, that is, one half the number of threads which the finished thread is to be. Then proceed to cut one of the threads, leaving the proper blank space between the convolutions for putting in the second thread. To locate this properly a tooth in the stud gear may be marked, and also mark the space in the intermediate gear into which this marked tooth has meshed. Now lower the intermediate gear out of the mesh, by unscrewing the clamp bolt of the stud-plate for the purpose, and turn the spindle exactly one half a revolution, that is, until one half the whole number of teeth have passed the marked space in the intermediate gear, and the marked tooth is exactly opposite its former position. Raise the stud-plate, putting the two gears properly in mesh with each other, and go on with the cutting of the second thread. This is assuming, of course, that the stud gear has an even number of teeth and that the ratio between the lathe spindle and the head shaft or gear spindle is 1 to 1, both conditions being the usual ones.

When this ratio is different, it is readily understood that the spindle must be rotated a *proportional* amount which is governed by this ratio.

Another method of accomplishing the same result is to have two dog-slots in the small face-plate exactly opposite each other, and after one of the double threads is finished, to shift the tail of the dog into the other slot.

Triple and quadruple threads are cut in a similar manner, but all the details of the work are much more complicated and difficult, both in making the proper calculations to insure the exact thickness or pitch of the threads, and in grinding and setting the tool so as to get the correct cutting angles and clearance.

Boring bars may be used in various ways. They may be supported on both centers and the work they are to bore strapped to the carriage. They may have one end fitted to the taper hole in the head spindle and the other end carried by the tail-stock center and the work held as before. Or, the boring bar may similarly be held in the tail-stock spindle and the opposite end supported in a bushing, in the center hole of the main spindle, while the work may be carried in one of two ways. That is, it may be strapped to the face-plate, or held in a chuck; or, if comparatively long, cylindrical

work, it may have one end held in a chuck and the other supported by a center rest.

The author once had a job of this kind to do and it was accomplished successfully by the arrangement described and illustrated as follows:

Given the task of boring a $5\frac{1}{8}$-inch hole endwise through a hard steel spindle $7\frac{1}{2}$ inches in diameter and 5 feet long, with a large and powerful boring lathe, such as is used on gun work, and the work would be comparatively easy and rapid. Having only the equipment of an ordinary machine shop, the case becomes more serious. In the regular course of business such a job was required to be done,

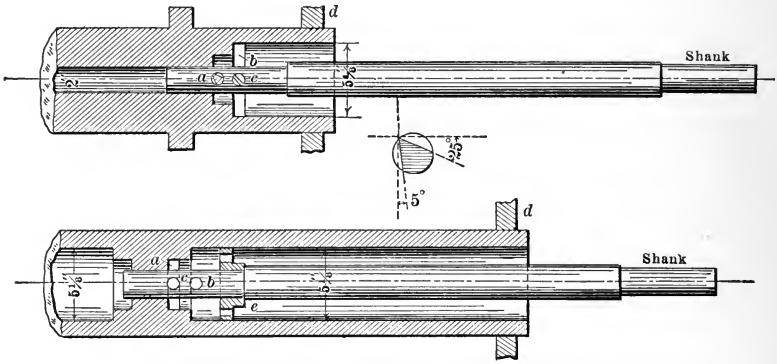


Fig. 222. — Boring Bar for a Long Hole.

and the work was performed perfectly and expeditiously, as will be described.

Fortunately, a boring lathe was at hand, fitted with a chuck and provided with a sliding carriage, operated by an automatic feed and designed to bore a $2\frac{1}{2}$-inch hole, 25 inches deep. One end of the spindle to be bored was fixed in the chuck and the other run in the jaws of a center rest, as shown at *d*, Fig. 222.

An expert blacksmith forged a twist drill 2 inches in diameter with a twist of 31 inches in length, which was turned up and finished, and with this a hole was bored a little over 30 inches deep. A soft brass tube of about $\frac{2}{10}$-inch bore, carried oil under pressure to the point of the drill and on its return brought out the chips. The spindle was then reversed and the hole was bored from the opposite end until the two holes met, which they did quite exactly.

Now came the work of enlarging the hole from 2 inches to $5\frac{1}{8}$ inches. It is to this part of the work that particular attention is called. As the means for holding the drill had proven very rigid and satisfactory, a boring bar was constructed, as shown in the upper illustration, Fig. 222. The cutters *a* and *b* were of $\frac{3}{4}$-inch round steel, fitted in the usual way, and held by set-screws *c*, the bar being placed in a lathe and its ends turned off, so that the cutter *a* would measure $3\frac{7}{8}$ inches, and *b* $5\frac{1}{8}$ inches. The end of the bar just fitted the 2-inch hole already bored in the spindle, thereby furnishing a correct and certain guide and support near the cutters. The cutting ends of the cutters were formed as shown at A, Fig. 222, *i.e.*, the face of the cutting edges being inclined 5 degrees and the leading edge 25 degrees, making the angle of the cutting edge 60 degrees, which proved to be a very effective construction, the cutter *a* enlarging the hole to the extent of taking out about half of the stock and the cutter *b* removing the remainder.

The spindle was then reversed and the operation continued from the opposite end until only a small portion of the 2-inch hole was left to guide the boring bar. The bar was then withdrawn and a disk *e* fitted to it. This disk was $5\frac{1}{8}$ inches in diameter, so as to just fit the enlarged hole and furnish a guide for completing the enlargement of the hole, as shown in the lower illustration.

The work was successfully done, a true, smooth hole bored, the two sections of which coincided perfectly. It will be noted that in this job the hole was very large in proportion to the exterior diameter, and a large amount of stock was taken out; in fact, nearly 350 pounds of hard steel. This was removed at the rate of nearly 30 pounds per hour.

The plan will doubtless commend itself for similar work, and where there is even a greater difference between the directing hole and the finished bore three or more cutters might be used to advantage.

It is frequently the custom to fit flat cutters in elongated mortises made through the bar instead of using a round cutter in a bored hole. The flat cutters will be proper when the boring bar is comparatively small in diameter, as it weakens the bar less than a round hole of sufficient diameter to carry a cylindrical cutter of the proper strength. Still the cylindrical cutter should be used

whenever possible, both for rigidity and cutting qualities as well as economy.

When large holes are to be bored a cross arm is used carrying a cutter on each end. Sometimes two cutters on each end are used, a roughing and a finishing cutter.

Sometimes a large hollow boring bar is used, carrying a cross-bar or head with two tools. This cross bar is arranged to slide on the boring bar and is fed forward by a screw passing through the center of the bar and having upon it a nut that is connected with the cross head. Such an arrangement is used for boring engine cylinders. These boring heads are often driven by the old "star-feed" arrangement, familiar to nearly all machinists.

These elaborate devices for boring are usually constructed for special boring machines and may hardly be considered as a part of the equipment of an engine lathe.

Milling may be successfully performed on a lathe by strapping the work to the compound rest, to the carriage or to a suitable fixture attached to either. While not so economical or so rapid as on a regular milling machine, it often proves very advantageous when a milling machine is not at hand or when the machines of the shop are crowded with work so as not to be available.

Many light operations of milling may be performed on a speed lathe, with proper fixtures for the purpose, particularly when the work is of brass or similar soft metals. In these cases the speed lathe will often turn out as much work as the plain hand milling machine.

Gear cutting can frequently be done on the lathe under similar circumstances to those referred to above. The necessary fixtures for holding and indexing the work may be comparatively simple and economical, a change-gear being frequently used as an index, and many jobs quite satisfactorily done in the absence of a regular gear-cutting machine.

Grinding is a common operation in the lathe and is referred to in the chapter on lathe attachments.

In the absence of a suitable machine designed for the purpose, cam cutting may be successfully done in the lathe, by the use of proper formers. The milling cutter for such operations is carried in the center hole of the lathe spindle, and the cam held by a suit-

able fixture attached to the compound rest, or to the carriage, as may be most convenient.

The work may thus be arranged so as to cut face cams or edge cams, and to mill the cam slots of irregular contour on either edge or face cams.

However, the question of cams is one of such great variety, and the devices necessary to properly handle them are so many, a detailed discussion of ways and means for doing the work does not seem proper in this place.

The practical and resourceful machinist will find many uses for the engine lathe that have not been here described, and if he is a progressive man he will discover many new uses and new devices for handling the many new kinds of work with which he will be confronted.

Whatever new and improved machines he may have available, or however well they may be adapted to his many wants, his principal dependence will be likely to be, in the future as in the past, on the engine lathe, "the king of machine shop tools."

CHAPTER XV

ENGINE LATHES

Definition of the word *engine*. What is meant by an engine lathe. The plan of this chapter. The Reed lathes. Reed 18-inch engine lathe The Pratt & Whitney lathes. Their 14-inch engine lathe. Flather lathes. Flather 18-inch quick change gear lathe. Prentice Brothers' Company and their 16-inch engine lathe. The Blaisdell 18-inch swing engine lathe. The New Haven 21-inch engine lathe. Two lathe patents by the author. The Hendey-Norton lathes. Who were the pioneers in quick change gear devices? The Hendey-Norton 24-inch engine lathe. The Lodge & Shipley 20-inch engine lathe.

A LARGE majority of the lathes in use in the machine shop or manufacturing plant are what have been known for years as engine lathes. Just why this qualifying designation of *engine* was applied to them is not clear, although we know that in former times the term engine was applied to many machines, particularly those of the higher class, and very early in the development of the mechanic arts the word seems to have been used to designate almost any kind of a machine. Thus we read in the Marquis of Worcester's "Century of Inventions," published in 1683, of "an engine that may be carried in one's pocket" for blowing up ships; "a portable engine in the way of a tobacco tongs"; "an engine whereby one man may take out of the water a ship of 500 ton," and so on, showing the strange uses to which the term engine has been put in times past, while at a comparatively recent period an indexing machine was called a dividing engine, while Webster says broadly that an engine is "a machine in which the mechanical powers are combined."

Recurring to the subject, by the term of engine lathe we mean that class or type of lathes which is usually so denominated mechanically and commercially, and which may be defined as a metal turning lathe, having a back geared head-stock; a tail-stock capable

of being set over for turning tapers; a carriage provided with suitable tool-supporting mechanism and having connected with it an apron carrying the necessary gearing mechanism for producing power lateral and transverse cutting feeds; and a lead screw, with suitable gearing for driving it, whereby the usual screw threads may be cut, through its proper connection with the apron mechanism.

With this conception of the design, construction, and office of the engine lathe of the present day, the following examples are presented and their special features discussed, with a view to the better understanding of this important machine tool. The engravings, the facts stated, and the dimensions, where the same are given, are derived from the machines themselves or their builders, or both, and the aim is to make the information as correct and the estimate of their practical utility as fair as is possible, so that what is here set down will be of value to the buyer of these machines; to the machinist who uses them; to the draftsman and designer who may desire to know of their individual peculiarities; and to the student who would learn valuable lessons in relation to the design and development of the Modern American Lathe.

While it is not expected or intended that the lathes of *all* makers shall appear in this connection, those of the more prominent builders will be introduced, and to these will be added such others as may possess particularly commendable or novel features, in order that the essential points of the engine lathe may be well and thoroughly illustrated and described, with a minuteness that their importance may demand.

Among the many manufacturers of lathes the F. E. Reed Company may deservedly receive the title of "ancient and honorable," not because the product of the concern deserves the name of ancient, but because of the long and honorable career of the establishment which has always stood for good materials, good workmanship, and practical design for every-day tools capable of standing up to the work, year in and year out, with whatever the machine tool market affords. While the company have always built substantial and practical tools, of ample strength and many conveniencies for the operator, they have not been given to the exploiting of mechanical fads and fancies or to going to extremes in any one direction.

As an example of the engine lathe built by this company, the 18-inch swing engine lathe shown in Fig. 223 is given. It will be seen that here is a deep and strong bed supported upon the older form of legs instead of cabinets. Upon the front leg is a special

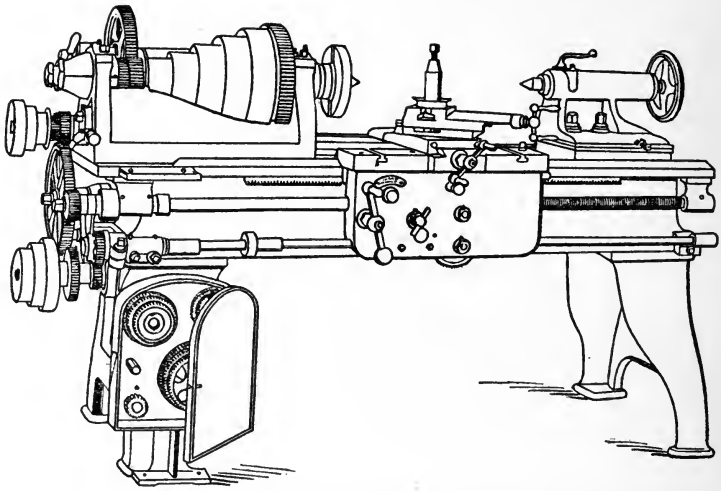


FIG. 223. — 18-inch Swing Engine Lathe built by the F. E. Reed Company.

cabinet for holding the change-gears which are of the older form of change-gears proper, that is, removable. The feed is by means of a belt upon the well-known three-step cone, with which is arranged a change of gears making six feeds.

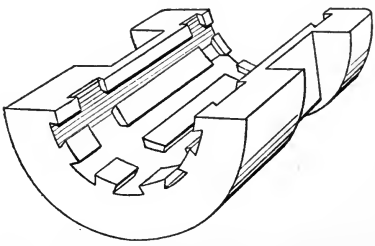


FIG. 224. — Spindle Box of the Reed Lathe Ready for Babbitting.

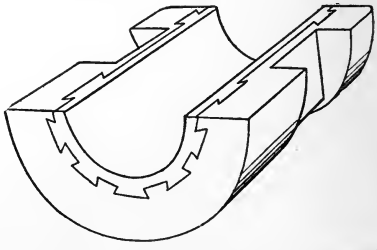


FIG. 225. — Spindle Box of the Reed Lathe after Babbitting.

The head-stock is heavy and strong and carries a spindle made from a crucible steel forging which runs in cast iron boxes lined with genuine babbitt metal, as shown in Figs. 224 and 225.

In the first of these illustrations is shown the cast iron box

properly milled out to fit the housings of the head-stock. After this operation it is bored out and then slotted ready to receive the babbitt metal lining. It will be noticed that these are all "dovetail" slots, the object of this form being to hold the lining metal securely in its place. The babbitt metal is cast into the box, after which it is compressed sufficiently to fill out any shrinkage that may have occurred upon cooling, and to render it more dense and durable. It is then re-bored, reamed, and hand scraped, so as to fit the spindle as perfectly as possible. Constructed in this manner there is nothing coming in contact with the spindle except the babbitt metal, which, when finished, has the appearance shown in Fig. 225.

Experience has demonstrated that with proper care on the part of the operator a box constructed in this manner will last for a very long time, and, if properly lubricated, that the babbitt metal will soon "glace" over and form one of the best bearing surfaces obtainable. The spindle is bored out to $1\frac{1}{4}$ inches. The driving-cone is of five steps, the largest being 12 inches and is adapted for a $2\frac{3}{4}$-inch belt. The carriage is of ample strength and has a long bearing upon the bed, and supports a very substantial compound rest. The carriage is gibbed to the outside of the bed both back and front. The apron is of ample dimensions, so as to afford space for large and strong operating parts, which are few in number and simple in construction.

The feeds include an independent rod and patent friction feed. Combined gear and belt feeds are furnished and also an automatic stop motion in connection with either type of feed. There is also provided a simple belt tightener device. The belt feeds are from 25 to 95 per inch inclusive. When a geared feed is wanted the belt can be removed and the feed rod connected with an intermediate gear. Then by changing the gears upon the feed stud of the head-stock, feeds may be obtained from 12 to 125 per inch, inclusive. Even this range of feeds seems rather fine for modern methods of work. The lathe will cut seventeen different threads from 2 to 20 per inch, inclusive. The rack and rack pinion are of steel and capable of disengagement when regular turning feeds only are required. An "offset" tail-stock is furnished.

The net weight of one of these lathes with an 8-foot bed is 3,080 pounds, by which it will be seen that ample weight is provided to

obtain a strong and rigid machine. The countershaft is furnished with patent friction pulleys which can be oiled while running, and with self-oiling boxes which will run six months with one oiling, and requiring no further attention.

This company make a variety of different styles and types of lathes, as well as attachments and accessories, which will be found described and illustrated further on in these pages and under their appropriate headings. The reader is referred to them for further information.

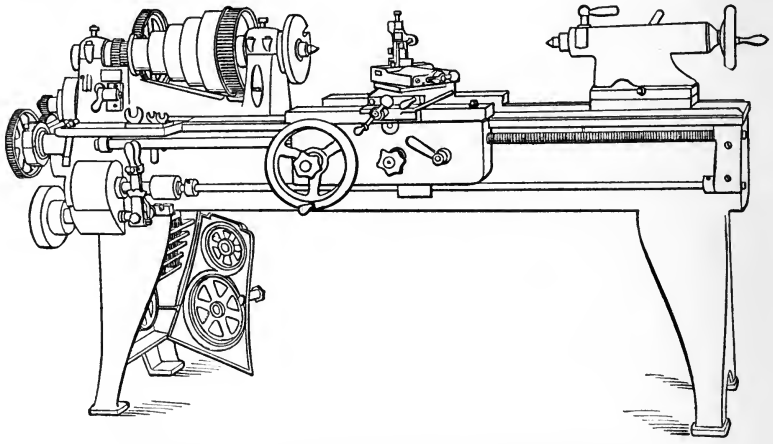


FIG. 226. — 14-inch Swing Engine Lathe built by the Pratt & Whitney Company.

Another of the old and reliable lathe building establishments is that of the Pratt & Whitney Company, which has for many years enjoyed an enviable reputation as makers of fine machine tools. While they have been progressive, and have brought out many valuable improvements they have never been prone to exploit mechanical fads, or to put on the market comparatively untried devices of the newest kind suggested by enthusiasts who imagined them capable of marvelous results. They have nearly always produced machines well and carefully designed, and constructed of good material and of excellent workmanship.

While the product of the company has been large and varied, a great deal of attention has been given to producing good lathes, a sample of which is given in Fig. 226, which is a 14-inch swing engine lathe of recent design. While rated as a 14-inch lathe it

swings nearly 16 inches over the bed, and, as a lathe of that capacity, is heavy and strong, with a deep and heavy bed supported on their well-known design of legs rather than cabinets. Still the net weight of a 6-foot bed lathe is 2,200, which is very heavy for a lathe of these dimensions.

The apron is shown in Fig. 227, in which it will be seen that it is of very strong construction, being made with two plates whereby the shafts have a support at both ends. The feed rod is carried in double boxes in which are carried right and left worms, engaging the two worm-gears which operate the feed mechanism. While the use of worms and worm-gears in a lathe apron cannot be commended,

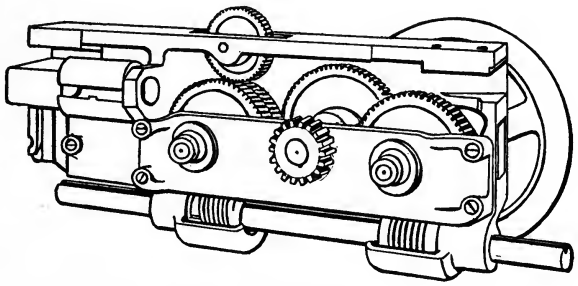


Fig. 227. — Apron of the Pratt & Whitney Lathe.

and the difficulties which most builders have found with them, have caused their use to be discontinued, this company still retain them and by very good construction render them successful.

The lead screw nut is well supported to stand the strain to which it is put, and altogether the apron is an excellent specimen of good material and workmanship. The double plates are a feature that ought to be adopted in all lathe aprons as it adds much to the strength of the mechanism, holds the shafts well in line by supporting them at both ends, and materially increases the wearing qualities of the various parts.

While the various sizes as have been given for the lathes of other builders are not at hand, it may be said that all bearings have more than usual diameter and length and the boxes are accurately scraped to fit ground journals. The head-stock is massive and well designed and provided with a five-step cone pulley.

The feed gearing is operated by a two-step cone, but has com-

pound gearing by which a large variety of feeds may be produced. The thread-cutting mechanism provides for cutting from 2 to 92 threads per inch, and by the use of the translating gears will cut all the usual metric threads.

Other lathes of different dimensions and types will be illustrated and described later on in this book and under their appropriate headings. For information of this kind the reader is referred to the chapters on these subjects.

The name of Flather has been so long and so intimately identified with the invention and the building of machine tools, that

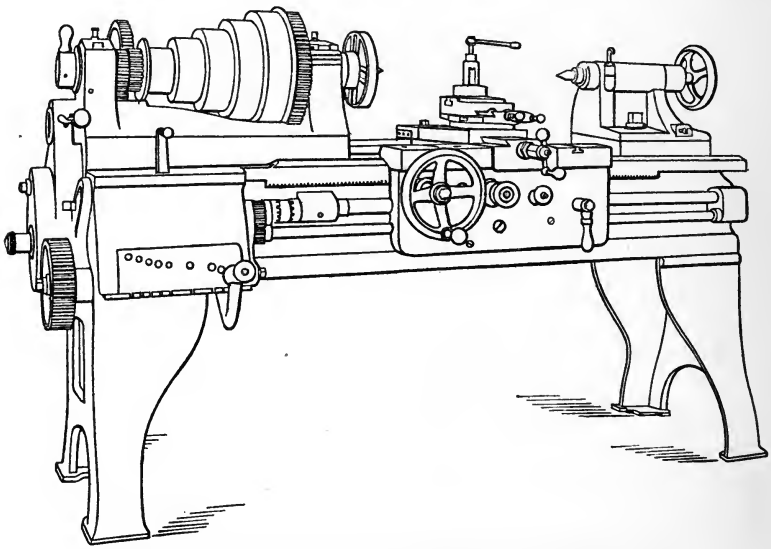


FIG. 228. — 18-inch Swing Quick Change Gear Engine Lathe, built by Flather & Co.

in the development of any type of them we naturally look for those bearing this name. In the improvements of the rapid change gear devices we find the names of Edward, Joseph, Herbert, and Ernest, each of whom have added something new to the "state of the art."

In Fig. 228 is given a front elevation of 18-inch swing "quick change gear lathe," which seems designed to meet the latest requirements, and which is powerful, strong and rigid, and combines a reasonable degree of simplicity with accuracy, ease of operation, good workmanship and material. The head-stock and

tail-stock are fitted to the bed with a V at the rear and a flat track in front, thus permitting the cross bridge of the carriage to be deep and strong. As will be seen in the engraving, the head-stock is heavy and strong with ample housings for the main spindle bearings, which are lined with genuine babbitt metal, cast solid in the head-stock, compressed, then bored out and scraped to an accurate fit for the ground journals of the spindle, which is made of hammered crucible steel. Its front bearing is 3 inches in diameter and $4\frac{3}{4}$ inches long. The bore of the spindle is $1\frac{1}{2}$ inches.

The spindle cone is of five steps and adapted for a $2\frac{3}{4}$-inch belt, or made of four steps for a $3\frac{1}{4}$-inch belt, as may be desired.

The carriage is gibbed on the inside and outside and has ample bearing on the V's, while the tool rests are unusually wide and long, and are supported the full length by the carriage, even when turning the largest diameters.

The feed mechanism is of new design and accomplishes in a simple and durable manner, and with as few gears as may be, all the results required in the most modern lathe. In a general way it may be described as attached to the front of the lathe in the form of a case in which a cone of nine gears is mounted upon a shaft, any one of which can be instantly engaged by simply moving the lever in front of the case. Upon another shaft located above the cone of gears and in line with the lead screw is a double clutch-gear controlled by the small lever on the top of the gear case. The shifting of this lever to three different positions increases the number of changes obtained by the lower lever to twenty-seven. This number may be doubled by sliding in or out a gear at the end of the lathe, thus giving fifty-four changes in all. An index attached to the front of the gear case shows the entire fifty-four changes, so that the operator may know instantly which lever it is necessary to move, and to what position to set it in order to obtain any of the different threads or the different cutting feeds shown upon the index, the entire mechanism being so simple that the most inexperienced operator soon understands its construction and its operation. The standard threads from 2 to 128, including $11\frac{1}{2}$, and feeds from 7 to 450 per inch, are readily obtained without removing a gear, while provision is made by which odd threads or feeds may

be had at little trouble or expense. All the gears in the gear case are of coarse pitch, and being cut from the solid are practically unbreakable.

The rack and pinion are cut from steel, as are also all the gears, studs and plates in the apron, insuring a great degree of strength and durability even under the strains incident to very heavy duty.

This company make the usual variety of lathes as built by other establishments, and all of them are of good workmanship and with the well-earned reputation for good tools.

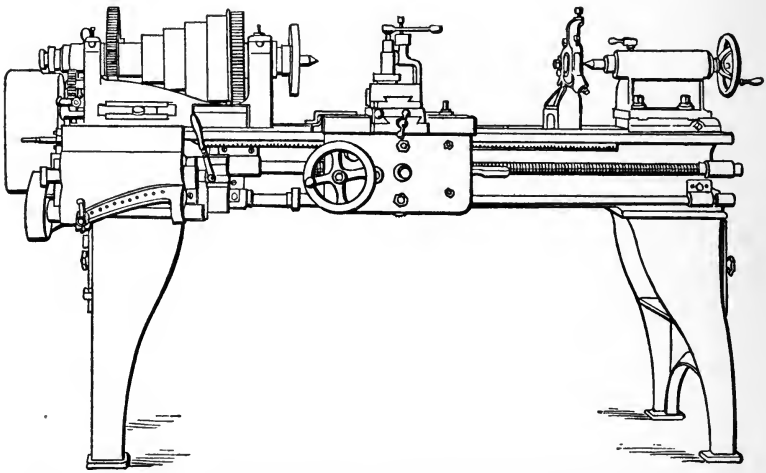


FIG. 229. — 16-inch Swing Engine built by the Prentice Bros. Company.

The Prentice Brothers Company have for years built lathes, good lathes, as must be judged by the fact that many hundreds of them have been sold and used all over the country. Among the older and more conservative establishments turning out this class of work, they have yet endeavored to meet the demands of modern methods, and in Fig. 229 is shown one of their 16-inch swing engine lathes, with a quick change gear mechanism and an "offset" tail-stock.

The head-stock is not as massive as in those of some other builders, though strong enough for most kinds of work which the lathe will be called upon to do. The spindle is of high carbon steel, with $2\frac{1}{2}$-inch by $4\frac{1}{2}$-inch front bearing and a $1\frac{1}{8}$-inch hole in the spindle. The spindle is driven by a five-step cone, arranged for a

$2\frac{1}{2}$-inch belt. The largest diameter of cone-step is 10 inches. The spindle runs in hard bronze bearings.

The quick change gear device contains the "cone of gears," so commonly used in these devices, and also a series of multiplying gears at the end of the head-stock, by means of which fifty-five changes may be made, from 2 to 60 threads per inch, and feed cuts from 10 to 320 per inch. All feeds are positive as no feed belts are used. The carriage and apron do not seem to be of sufficient length or weight to stand up rigidly to very heavy cuts with the use of high-speed tool steel. Neither does the bed seem to be as heavy, at least as deep, as we would expect to find in a modern lathe adapted to doing the heavy duty now expected of such a lathe. The lathe with a 6-foot bed weighs when boxed for shipment 1,850 pounds.

The "offset" tail-stock is a very useful feature, which is patented by the manufacturers and about which there has been much dispute with other builders who have made them from time to time.

Other than this feature and the quick change gear device the lathe appears to be their regular and well-known product of engine lathes.

The company make the usual variety of engine lathes of special design for special work as well as their plain lathes. These special machines, as well as various attachments and accessories, will be illustrated and described in future chapters, later on in this book, and attention called to their special features.

In 1865 P. Blaisdell began the building of lathes and has continued the business since. While no great efforts seem to have been made to bring out new and novel inventions, the Blaisdell lathes have always been known as machine tools, that are well made, reliable, and practical.

In Fig. 230 is shown an 18-inch swing lathe of their manufacture, that is a good example of their regular line of product.

The head-stock of this lathe has a cone of five steps which take a $2\frac{3}{4}$-inch belt. The spindle is made from hammered, cast crucible steel, and is bored out to $1\frac{1}{2}$ inches. The boxes are of gun metal or of cast iron lined with genuine babbitt metal, as may be preferred. The back gear ratio is 11 to 1, which is high for a lathe of this swing.

The lathe has a power cross feed with micrometer graduations

for the cross-feed screw. There is furnished a rapid change gear device for feeding from 13 to 339 per inch, and a new and powerful friction warranted not to slip. There is a patented automatic stop on the feed rod. The lead screw will cut threads from 2 to 23, including $11\frac{1}{2}$ pipe thread. The net weight of this lathe with an 8-foot bed is 2,400 pounds.

This company make a variety of lathes and lathe attachments and accessories, some of which are shown later on in this book, and under the appropriate heading, to which the reader's attention is directed if interested in this class of the product.

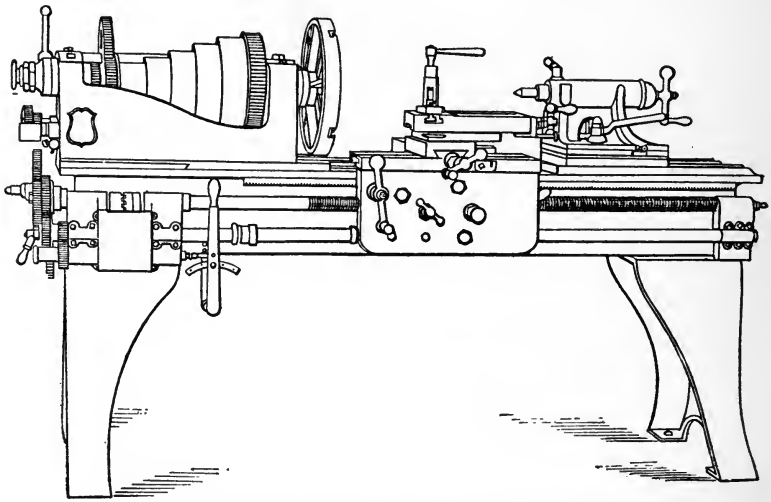


FIG. 230. — 18-inch Swing Engine Lathe, built by P. Blaisdell & Co.

The New Haven Manufacturing Company are among the older establishments building engine lathes, and for a number of years have built a line of very strong and substantial tools, notable not so much for fine finish as for rigidity and for practical utility, special attention having been given to the quality of the materials entering into them.

Figure 231 gives a front elevation of their 21-inch swing lathe, and Fig. 232 is an end view of the head and bed, showing the feeding and thread-cutting gears. The arrangement of the former is peculiar and the subject of a patent granted to the author. In this case there is fixed upon the outer end of the head-shaft a "cone of

gears," with each of which is engaged an idle gear running loosely upon a stud fixed to a revolving plate, secured in any desired position by a spring pin as shown in the end view of the lathe.

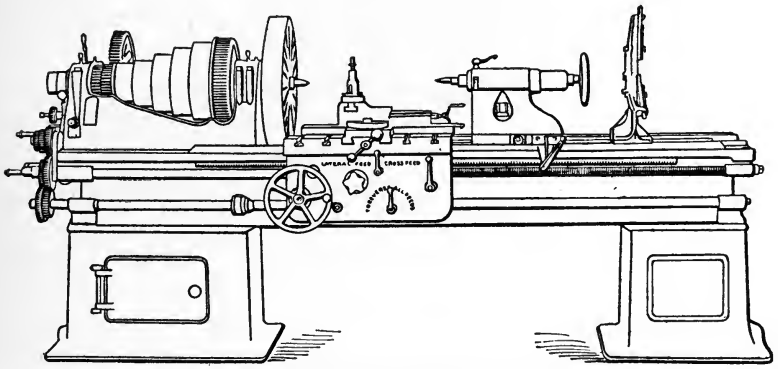


FIG. 231. — 21-inch Swing Engine Lathe, built by the New Haven Manufacturing Company.

When in either of the three operative positions, one of these idle gears connects the cone of gears on the head-shaft with a reversed cone of gears running loose upon a stud in an arm of the stud-plate, and one of them engaging with the gear running loose upon the lead screw, which gear in turn engages with a gear fixed to the feed rod. By this arrangement the plate carrying the three (or more) idle gears may, by revolving it to any one of its several positions, successively connect the different size of gears composing the cone of gears, and so, at one motion, changing the rate of feed. By the changing of a pin passing through the hub of the feed-rod gears, another series of feeds may be obtained. The engraving shows a revolving plate carrying but three idle gears. It is obvious that any reasonable number of idle gears may be carried and that

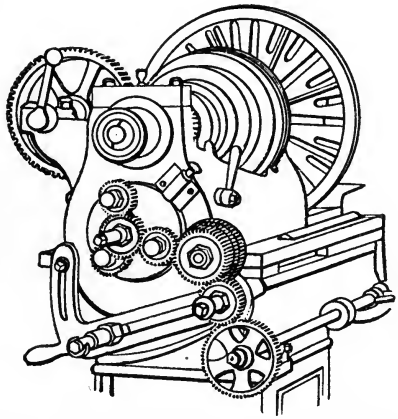


FIG. 232. — End Elevation of 21-inch New Haven Lathe.

by the use of multiplying gears these ratios may be had in several series of numbers. The object of mounting the second cone of gears upon a stud fixed in an arm cast integral with the main part of the stud-plate (shown in its inactive position) is so that when the regular change-gears are mounted upon the head-shaft and lead screw, and an idler placed upon the idler stud, and the stud-plate raised to an active position for the purpose of engaging the three change-gears thus mounted, the second cone of gears will be thrown out of their active position and the operation of the feed rod stopped. This same device may be applied to the cutting of threads if desired, by the addition of gears to the cone, and the use of multiplying gears to get ratios of 2 to 1, 3 to 1, and 4 to 1.

Within the head-stock is a device for handling the reverse gears, consisting of a horizontal shaft operated by the handle seen in the front of the head, and having upon it a cylindrical cam cut with a groove consisting of two movements and three rests, in which is engaged a hardened steel pin fixed in the yoke-plate, carrying the reversing gears. By this arrangement the yoke-plate is readily locked in its "forward," "back," and "out" positions, and held perfectly rigid when moved from one position to the other. This device was also invented and patented by the author. Either of these devices can be operated while the lathe is in motion, without danger of breaking the teeth of the gears.

These lathes have hollow spindles and the one shown in the engraving is made to the following specifications. The beds are wide, deep and strongly braced and mounted upon cabinets of liberal dimensions. The width between the V's is such as to form the base of an equilateral triangle, whose apex is the center line of the lathe. The heads are very strong and rigid, having a solid web entirely across under the cone pulley. The spindle is bored out to $\frac{1}{1}\frac{3}{6}$ inches and runs in nickel bronze boxes. The front bearing is $3\frac{1}{2}$ inches in diameter and $5\frac{1}{4}$ inches long. The spindles are powerfully back geared and have hardened steel bushings and check-nut for taking up the end thrust. Cone pulleys have five steps of $5\frac{3}{4}$ to $13\frac{3}{4}$ inches diameter, and adapted for a 3-inch belt. The tail-stock is very rigid, with a "set-over" for turning tapers and is secured by two heavy steel bolts. The tail spindle is $2\frac{3}{8}$ inches in

diameter and bored for a No. 4 Morse taper. The carriage is heavy and has a long bearing on the V's, to which it is scraped and fitted the entire length, and is gibbed at the front and back to the outside of the bed. It has power cross and lateral feeds, an automatic stop and a compound rest with a graduated base. The tool is adjusted as to height by a hardened steel concave ring and washer. The apron is very heavy, the operative parts simple and very strong. No worm-gears are used, their usual office being performed by a large bevel gear and two sliding bevel pinions, by which the motion is reversed. This sliding movement also operates a simple locking mechanism by which the thread cutting and feeding operations become entirely independent of each other, and each, when in operation, locks the other out automatically. The six regular changes of feed are 18, 25, 30, 40, 50, and 60 revolutions per inch of movement for both lateral and cross feed. All feed racks, rack pinion, studs, rod and lead screw, are made of special steel, and all nuts are case hardened.

It will be noticed in the engraving of the front of the lathe that all movements, including those of reversing, are controlled by levers in the front of the apron, so that the operator need not, necessarily, leave his place for this purpose.

A 21-inch swing lathe with a 10-foot bed weighs 3,800 pounds.

This company manufacture several other types of lathes and lathe attachments, which will be illustrated and described later on in this work and in connection with similar devices built by other makers.

It is said in a catalogue now on the author's desk that "the name Hendey-Norton has come to be generally recognized as being the pioneer in that class of lathes made commercially successful, having the mounted system of gearing for thread and feed changes." As to how far this claim is correct, is a proper matter for the mechanical public to judge. The phrase "commercially successful" seems to have been well put in connection with the statement and may possibly be its "saving grace," for it is well known that as early as 1868 Humphreys used the much discussed "cone of gears," and that he wrote in his patent, "I place my gear-wheels upon a shaft A, ranging from the smallest to the largest," while in 1892 Norton says in his patent, "on the shaft A, and within the box B,

are secured a series of gear-wheels E, of varying diameters, arranged step-like," etc. As to who was the pioneer may be an open question, as are a great many relating to the matter of patented inventions.

In Fig. 233 is shown a front elevation of the Hendey-Norton lathe of 24-inch swing, and is a late development of this establishment. The head-stock is provided with a "tie" from front to rear housing, which gives additional rigidity to the head-stock and prevents undue vibration of the spindle and its work. The spindle, which is bored out to $1\frac{3}{4}$ inches, runs in annular bearings of special

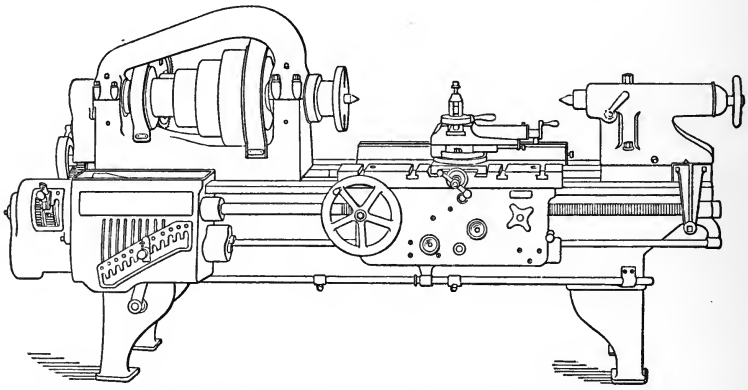


FIG. 233. — 24-inch Swing Engine Lathe built by the Hendey Machine Company.

metal and having taper bearings for the journals. The front bearing is $3\frac{5}{8}$ to $4\frac{5}{8}$ inches in diameter and $7\frac{1}{8}$ inches long, while the rear bearing is $3\frac{1}{4}$ to 4 inches in diameter and $5\frac{1}{4}$ inches long. Both these journals are not only self-adjusting, but adjustable, independent of each other, and allow for contraction and expansion of the spindle without disturbing the adjustment. The bearings are also self-oiling, having automatic oiling rings, running in large reservoirs of oil, with provision for catching the oil and returning it to the reservoir for use over again.

The construction of this spindle and its appendages for the smaller lathes is well shown in the longitudinal section given in Fig. 234, which shows a very clever piece of mechanical construction and one well adapted to the purposes for which it is designed.

This view in connection with the end elevation and partial section given in Fig. 235 shows the internal construction of the feeding

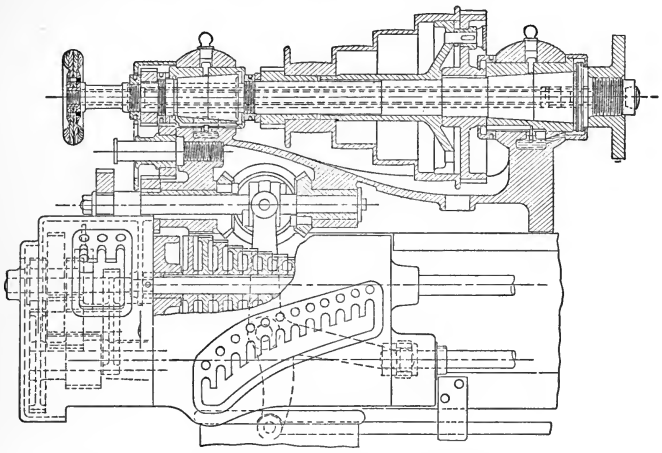


FIG. 234. — Longitudinal Section of the Head-Stock of the 24-inch Hendey-Norton Lathe.

and thread-cutting mechanism and the gearing necessary to accomplish the results according to Norton's plan.

The lathe is provided for automatically stopping the carriage

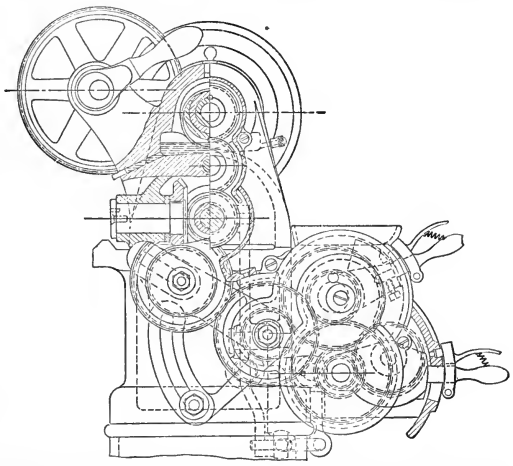


FIG. 235. — End Elevation of the 24-inch Hendey-Norton Lathe.

in either direction when either feeding or thread cutting, and for reversing the travel of the carriage by an apron lever.

The spindle cone has but four steps instead of five, as is usual with other makers, their diameters being from 6 to 15 inches and adapted for a $3\frac{3}{4}$-inch belt. The lathe will cut threads from 1 to 56 per inch and has a turning range of feeds from 5 to 280 per inch. The 24-inch swing lathe will turn $15\frac{1}{2}$ inches over the carriage. The tool-post takes in tools $\frac{5}{8}$ by $1\frac{1}{4}$ inches. The carriage has a bearing of 34 inches on the bed and is provided with a strong and well designed apron, excepting for the fact that worms and worm-gears are still retained as a part of their construction, notwithstanding the fact that even the best construction of this type is liable to injury from the carelessness of the operator and the lack of a plentiful supply of oil. The tail-stock is strong and rigid, and carries a $2\frac{7}{8}$-inch spindle bored and reamed for a No. 4 Morse taper. The weight of a 24-inch swing lathe with a 10-foot bed is 5,450 pounds, by which it will be seen that it is relatively a heavy lathe, considerably more so than that of many of its competitors.

This firm make other types or modifications of their lathes, and also some very desirable attachments and accessories for lathes which are illustrated and described under their appropriate headings further on in this work.

The Lodge & Shipley Machine Tool Company have turned out some good examples of modern machine tool building, in the recent types of their engine lathes, showing much consideration and study of the conditions surrounding the manufacturing problems of the present day. This is noticeable in their 20-inch swing engine lathe, a front elevation of which is shown in Fig. 236.

In this lathe the back gear quill and pinion are of forged steel instead of cast iron, as usual, whereby great strength and durability may be expected of this part, which in ordinary lathes not infrequently fails and has to be renewed. The cone pinion is also of forged steel. The main spindle is of 55 point carbon-steel and hammered, and has a $1\frac{3}{4}$-inch hole through its entire length. The front bearing is $3\frac{1}{2}$ inches in diameter and $5\frac{3}{4}$ inches long, and both bearings are accurately ground and the boxes have an oil reservoir beneath them from which oil is raised by small buckets attached to a brass ring located midway on the journal, thus insuring abundant lubrication. Gage glasses at the front of the head-stock show the level of oil in these reservoirs, which are deep enough to

permit sediment to settle at the bottom out of reach of the oil-raising buckets, thus keeping the lubricant on the journal clean and in good condition. The thrust collar is of steel, hardened and ground.

The general arrangement and construction of the head-stock, and the gearing contained in the front end of the bed, is well shown in the longitudinal section in Fig. 237, and the end elevation in Fig. 238. In these engravings the location of the "cone of gears" is seen to be in the bed of the lathe instead of in a box or extension

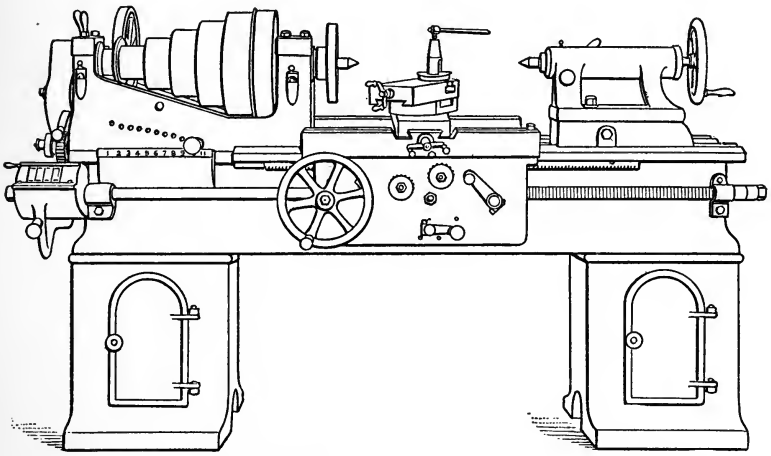


Fig. 236. — 20-inch Swing Engine Lathe built by the Lodge & Shipley Machine Tool Company.

in front of it, or partially in the head as is the case of some of the rapid change gear devices. In Fig. 238 the location of the various handles and levers for controlling the change gear device is clearly shown and their use and operation may be readily seen and understood. The movable or sliding connecting or intermediate pinion, carried by a lever which is held in place by a spring pin entering any one of the line of holes shown in the front of the head-stock in Fig. 236, is practically the same as used in the Hendey-Norton lathe and in others of this type. These changes are very quickly and certainly made, and the mechanism appears to be substantial and durable.

The bed is designed with ample depth and width, and is strongly

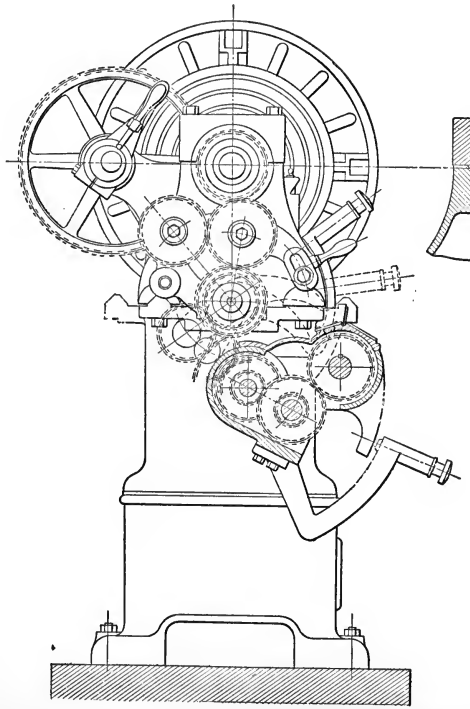


FIG. 238. — End Elevation of the Lodge & Shipley 20-inch Lathe.

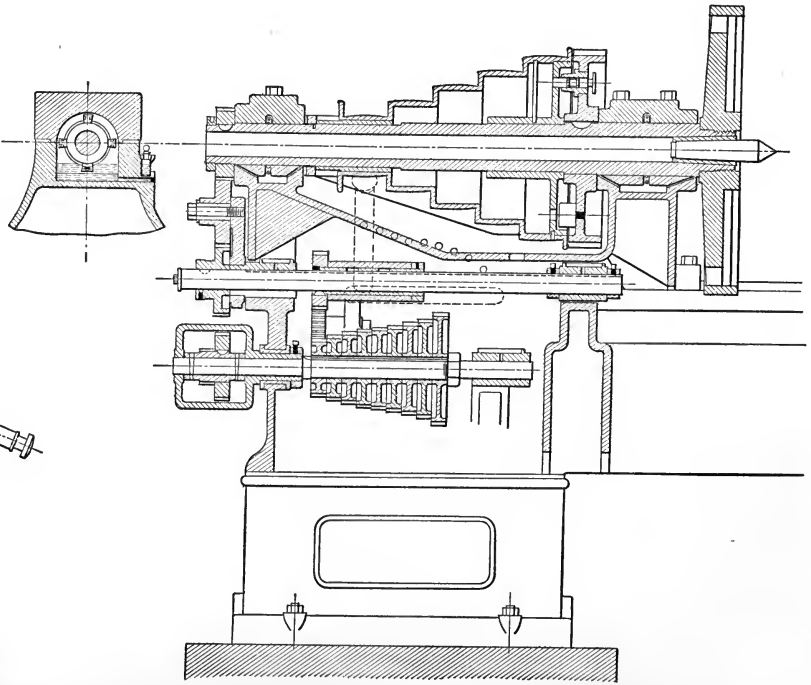


FIG. 237. — Longitudinal Section of the Lodge & Shiply Head-Stock for 20-inch Lathe.

braced internally by cross girts The surfaces to which the lead-screw bearings are fastened are planed to receive them and the parts are tongued and grooved to insure perfect alignment. The V's are rounded on top to prevent bruising. In lathes of 22-inch swing and larger the beds are additionally strengthened by a central longitudinal brace, in the top of which is a rack into which a pawl pivoted to the bottom of the tail-stock engages, thus affording a positive brace for holding the latter in position against heavy strains. The rear end of the bed is cut down low enough to permit the ready withdrawal of the tail-stock, which is very convenient when turret slides or similar attachments are to replace the regular tail-stock.

The carriage is strong and heavy with liberal length of bearing upon the V's the entire length of the carriage, which is gibbed to the bed its entire length also. In place of an inside V at the front of the bed, the surface is flat for the carriage to find an additional bearing, thus shortening the distance between the supports of the carriage and so affording additional strength and rigidity immediately under that portion supporting the compound rest in its usual position. The V's are kept clean and also lubricated by a specially designed wiper and oiler fastened to the ends of the carriage. This not only insures the proper lubrication but prevents grit and dirt getting between the carriage and the V's, and so destroying their accurate bearing and smooth surface contact.

The apron is of ample strength and made specially rigid by three braces through its entire length and a longitudinal brace across the bottom. It is tongued and grooved into the carriage, and firmly bolted to it. No worm or worm-gears are used, a compact arrangement of a large bevel gear and two bevel pinions mounted in a sliding frame taking the place of the older method of construction. There are few gears used in this construction, and all of them are of steel and run on hardened and ground steel studs or shafts. The lead screw passes through the double bevel pinions, and is splined to them by a spline reaching the entire length of the gear sleeve, the edges of the spline being carefully rounded to prevent the possibility of injuring the split nuts, which are made from solid metal and then split, instead of being lined with babbitt metal as usual. These nuts are held in planed grooves in the

back of the apron, no clamps or screws being used. This holds them very rigidly under the heaviest strains. In the larger lathes it is, of course, necessary to back gear the operative parts for ease of handling. This is done with few gears, which are made heavy and strong. The lead screw threads are never in use except when thread cutting, the locking out of the thread cutting or the regular feed device being automatically and surely provided

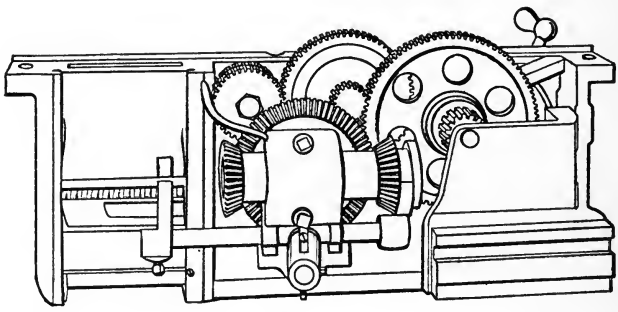


Fig. 239. — Apron of the Lodge & Shipley 20-inch Lathe.

for by a simple device. The rear of this apron is shown in Fig. 239, by which its compact form and mechanical design is clearly shown.

This establishment builds other types of lathes of very practical and useful forms and equally good design, as well as various attachments and accessories which will be found illustrated and described further on in this book under their appropriate headings, and to which the reader is referred for information of this character.

CHAPTER XVI

ENGINE LATHES CONTINUED

Schumacher & Boye's 20-inch instantaneous change gear engine lathe. Emmes change gear device. 32-inch swing engine lathe. Le Blond engine lathes. 24-inch swing lathe. The Le Blond lathe apron. Complete drawing of a front elevation. The Bradford Machine Tool Company's 16-inch swing engine lathe. The American Tool Works Company's 20-inch. The Springfield Machine Tool Company's 16-inch engine lathe. The Hamilton Machine Tool Company's 18-inch swing engine lathe. The W. P. Davis Machine Company's 18-inch swing engine lathe. The Fosdick Machine Tool Company's 16-inch swing engine lathe.

THE firm of Schumacher and Boye build a line of well-designed and practical engine lathes, one of which, called by the makers their "20-inch instantaneous change gear engine lathe," is shown in Fig. 240.

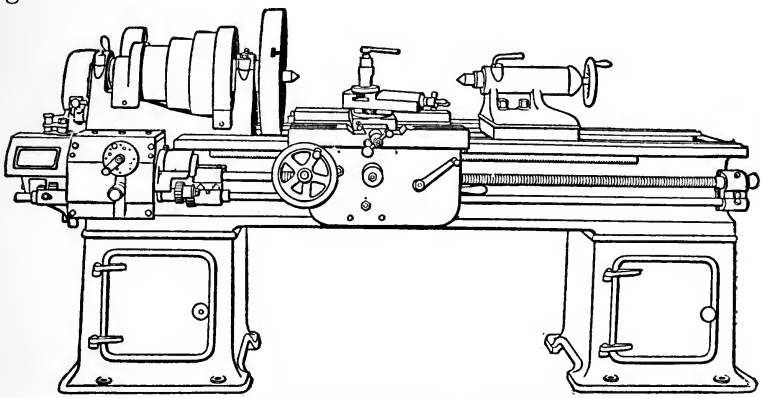


FIG. 240. — 28-inch Swing Instantaneous Change Gear Engine Lathe built by Schumacher & Boye.

It will be noticed that the spindle cone has but three steps, respectively 9, 11, and 13 inches in diameter, and adapted for a $3\frac{1}{2}$-inch belt. As the head is double back geared, the requisite

number of different speeds is obtained, the back gear ratios being $3\frac{1}{2}$ to 1, and 10 to 1. The front bearing of the main spindle is $3\frac{1}{8}$ inches in diameter and 6 inches long. The spindle has a $1\frac{9}{16}$-inch hole through its entire length, and reamed for a No. 4 Morse taper.

The change gear device is the one patented by Emmes, in 1902. and is very effective as a piece of practical mechanism, and is operated by a front and a top lever, swinging upon centers and carrying index pins which enter any one of a circle of index holes. Sliding pinions are also used upon the feed rod to still further enhance the value of the mechanism by providing for the operating or the disconnecting of the feed rod. The reverse for both feeding and thread cutting is handled at the head, and in the apron, as may be desired. The cutting feeds are locked "out" while threads are being cut, and vice versa. Forty changes of feeds and for thread cutting is provided for. The apron is constructed on simple and strong lines and is effective in withstanding the strains and shocks to which it is subjected. All the gears in it are made from drop forgings. The lathe with an 8-foot bed weighs 3,850 pounds.

This establishment makes lathes up to 48-inch swing, those of 32-inch swing and upward being provided with triple geared head-stocks which are built very strong, heavy, and rigid. These larger lathes all have the "instantaneous change gear" device, practically the same as that provided for the smaller lathes. The aprons of these lathes are of the box form and of very rigid construction, avoiding overhang as much as possible, and also the straining of pinions and studs. These studs are made of tool steel and run in bronze-lined boxes. The lead screw nuts are also of bronze. The main spindle, in the head-stock, is of 75-point carbon, crucible steel, has a $3\frac{1}{8}$-inch hole, and runs in phosphor bronze boxes. It is reamed for No. 6 Morse taper. The carriage has bearings through its entire length on the V's, and is gibbed both back and front. The compound rest has an angular feed by power with 12 inches travel. The apron and compound rest have steel gears throughout. The tail-stock is provided with a pawl which travels in a rack formed in the bed similar to those shown by Lodge & Shipley. The 48-inch lathe will swing 31 inches over the carriage. The lathe with a 14-foot bed weighs 17,500 pounds, and is a very strong and rigid lathe.

This lathe has forty changes of feeds and also the same number for thread cutting.

The company make the usual variety of lathe attachments and accessories necessary to fitting out their lathes with modern conveniences, which will be mentioned later and under headings that follow this in proper order. Many of these have found their way into the best machine shops of this country, and are much appreciated.

The LeBlond manufacture of lathes, like their milling machines, are well known in the market, and are noted for their good and careful design so as to properly meet the requirements which they have to fulfil. They are made from a good system of standard plugs, jigs, and templets, by which all the component parts are rendered interchangeable.

The spindles are all made from hammered crucible steel and finished by grinding. The boxes on the smaller lathes are composed of phosphor bronze, while those of the larger and heavier lathes are lined with genuine babbitt metal. The lead screws are made from 20-point carbon open hearth steel and are not splined, whereby the accuracy of the screw is maintained for good thread cutting. Thread-cutting stops are graduated in thousandths of an inch and right or left hand threads are arranged for by a reverse in the head.

The lateral and cross feeds are automatic and are properly graduated for good work. The aprons are unusually heavy and so arranged that it is impossible to throw in the rod feed and the lead screw feed at the same time. The rack pinion can be freed from engagement with the rack by lowering it out of its engaged position so that there is no undue resistance when thread cutting is to be done. It frequently happens that much friction is caused by these strains upon the moving parts of the apron and cause serious inconvenience and often damage or breakage to the ports, particularly to the rack pinion.

The tail-stock set-over arrangement is graduated so that tapers may be readily determined. They are of the overhanging type, frequently referred to as "the English style," whereby the compound rest may be swung around to a position almost parallel with the lathe bed.

The feed cones on the 12-inch to 24-inch swing lathes are so arranged that there are tighteners to apply to an improved chain-feed device so that there is none of the usual troubles from feed devices driven by belting. On the larger lathes there is provided an improved chain device, giving three independent feeds on the feed rod, and which can be changed instantly by a lever in the front of the head-stock.

While this establishment makes several types of lathes, it will be sufficient for our purpose here to introduce the regular engine lathe, and that of 24-inch swing is taken as a good example and shown in Fig. 241, which gives a front elevation, while Fig. 242

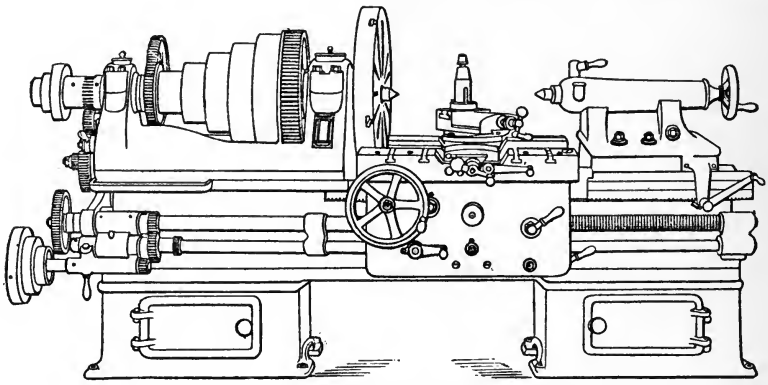


FIG. 241. — 24-inch Swing Engine Lathe built by the R. K. Le Blond Machine Tool Company.

is an end elevation showing the change gearing. The general description of this lathe is as follows:

The range of threads that can be cut is from 1 to 16 per inch. The main spindle is bored with a $2\frac{1}{16}$-inch hole and the front end bushed for a No. 5 Morse taper. The front bearing is $4\frac{3}{8}$ inches in diameter and 8 inches long. The lathe is driven by a five-step cone, the steps being from 6 to 17 inches in diameter and adapted for a $3\frac{1}{2}$-inch belt. While rated as a 24-inch swing lathe, it really swings $25\frac{1}{4}$ inches over the bed and 16 inches over the carriage. As a 10-foot bed lathe takes in 4 feet 4 inches between centers, it is seen that the head-stock and tail-stock occupy a space of 5 feet 8 inches on the bed, giving the opportunity to make both of these important features strong, rigid, and massive. As a 10-foot lathe

weighs 5,900 pounds net, it is seen that the weight is 590 pounds per foot. Countershaft pulleys being 16 inches in diameter, and for 5-inch belt assures ample driving power, and which, run at 120 and 165 revolutions per minute, give a spindle speed of $2\frac{3}{4}$ to 460 revolutions per minute, which is as wide a range as would possibly be needed in a very large variety of work.

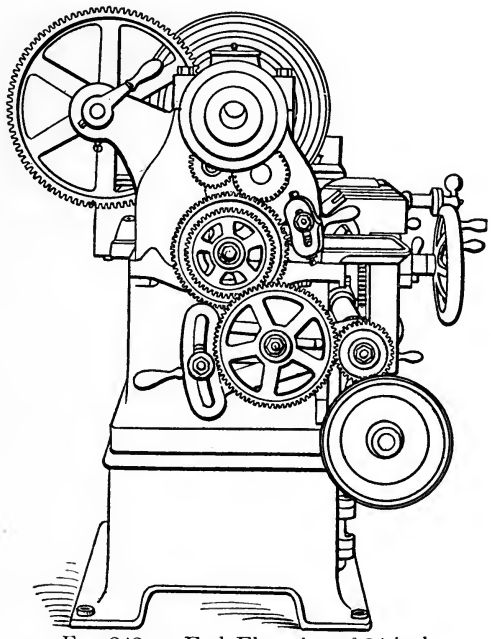


FIG. 242. — End Elevation of 24-inch Le Blond Lathe.

In the end elevation, shown in Fig. 242, the two stud-plates and the system of change gearing is clearly shown, and a good idea is given of the strength and stability of the lathe.

The operative parts of the apron of the smaller sizes of Le Blond lathes is shown in Fig. 243, by which it will be seen that they are very simple, and that therefore the parts may be made of sufficient strength to withstand the hard usage to which a lathe is often subjected. The operation of this mechanism is so simple that a detailed description does not seem necessary, although attention is called to the very simple manner of locking the rod feed out when the lead screw feed is in operation, and vice versa.

As no engraving of the exterior of a lathe can give a proper and correct idea of its interior construction, a full and complete drawing of a front elevation of this lathe is given in Fig. 244, particularly to illustrate this lathe and in a general way to show the construction of a modern engine lathe of a substantial and practical type for heavy, every-day work, and showing its general symmetry and good proportions.

The Bradford Machine Tool Company have recently developed a line of lathes which compare very favorably with those of other builders and possess some excellent features of strength, durability, and convenience for straight, every-day machine shop work.

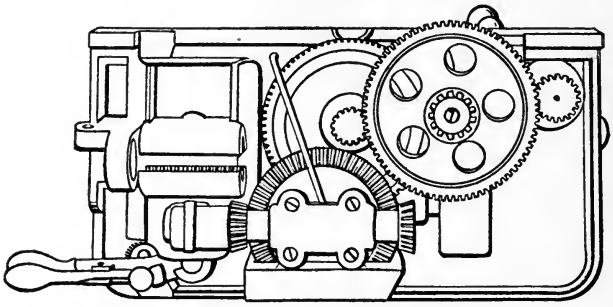


FIG. 243. — Apron of the 24-inch Le Blond Lathe.

In the design and construction of these lathes there are several noticeable features that may well be mentioned. None of them have cabinet legs. The old-style belt feed is used in nearly all of them. One of the exceptions is the 16-inch swing lathe which is adapted for tool-room work and has the rapid change gear device, patented by Johnson, which gives a wide range of turning feeds and thread-cutting pitches.

A front view of one of these lathes is given in Fig. 245.

The reverse in the head-stock of these lathes does not seem to be particularly effective. A tightening device for the feed belt on most of these lathes is handy and practical. There are other special features which will be noticed later on.

The main spindles of these lathes are of hammered crucible steel with adjustable, taper, bronze boxes; the journals (as well as all other cylindrical bearings of the lathe) are ground. In the 16-inch lathe the spindle is bored out to $1\frac{1}{8}$ inches.

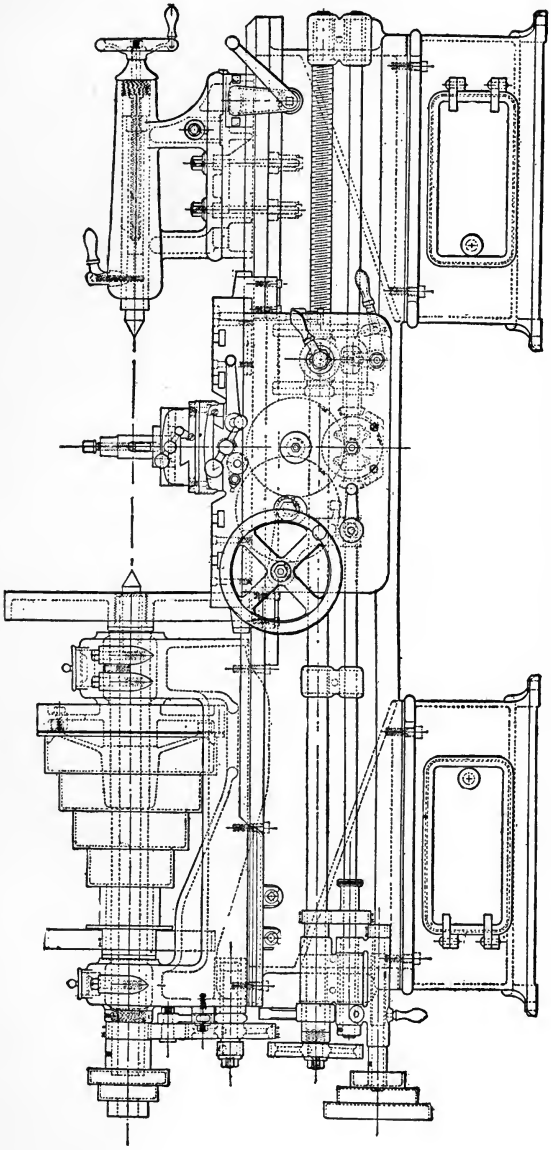


FIG. 244. — Complete Design of the 24-inch Le Blond Lathe.

The head cone is of five steps and adapted for a $2\frac{1}{2}$-inch belt. The lathe swings $10\frac{3}{8}$ inches over the carriage. The carriage and apron are of ample dimensions and the requisite strength for all practical purposes. The lathe is back geared $9\frac{1}{4}$ to 1. A 6-foot lathe weighs 2,000 pounds.

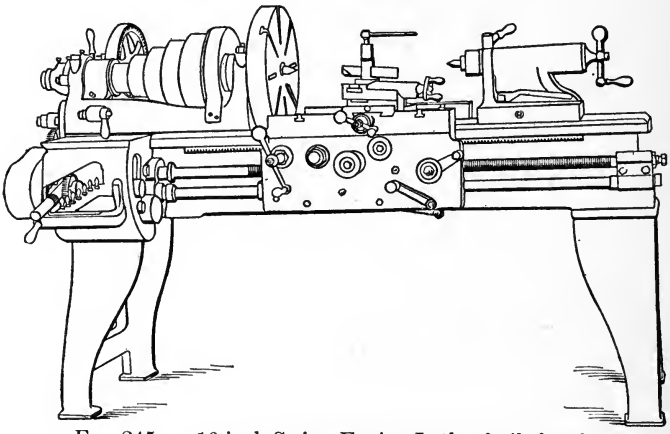


FIG. 245. — 16-inch Swing Engine Lathe, built by the Bradford Machine Tool Company.

This lathe will cut threads from 3 to 46 to the inch, and has a ratio of feeds of $4\frac{1}{2}$ times the number of threads per inch.

Figure 246 is a longitudinal section of the head-stock, giving a

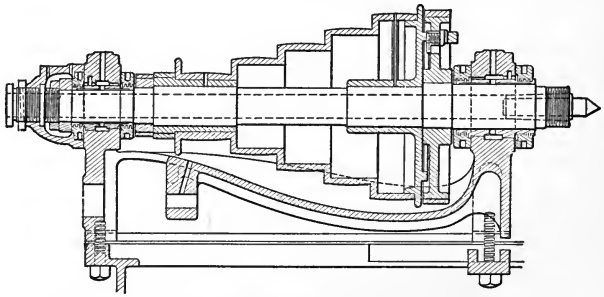


FIG. 246. — Longitudinal Section of the Head-Stock of the16-inch Bradford Lathe.

clear idea of the construction of the spindle, boxes, thrust bearings, and housings, as well as the form and strength of other parts of the head-stock. The thrush bearing is upon a fiber washer supported by a thrust screw and adjusting nut.

A rear view of the apron is shown in Fig. 247, by which it will be seen that worms and worm-gears are avoided and the substantial arrangement of a large bevel gear and double bevel pinions, mounted in a sliding form, takes its place. The locking device for preventing the interference of the thread-cutting and turning feeds with each other is clearly shown. The smaller pinions and the large rack gear are of steel and the rack pinion is capable of being withdrawn when thread cutting is being done.

The carriage is scraped to the full bearing of its entire length on the V's and is gibbed at both back and front to the outside of the bed. It is made deep and strong and has power lateral and cross feeds in all sizes of lathes.

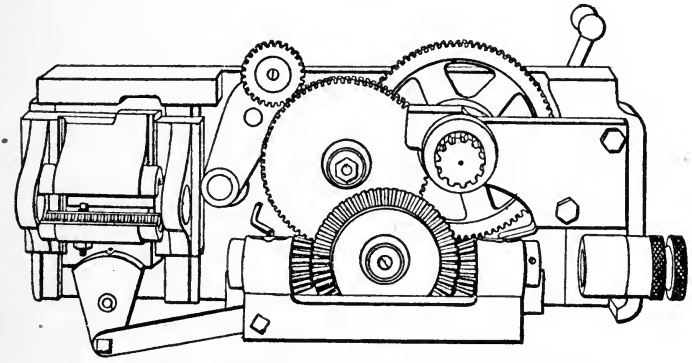


FIG. 247. — Apron of the 16-inch Bradford Lathe.

This company make a variety of different types of lathes and attachments for them, which will be illustrated and described under appropriate headings and later on in these chapters.

The American Tool Works Company is a comparatively new concern and is, therefore, unhampered by old traditions and the somewhat inconvenient inheritance which burdens some of the older manufacturers, that is, an accumulation of old designs and older patterns.

In Fig. 248 is given an illustration of their 20-inch swing engine lathe, which has a rigid and strong appearance and mechanical design that speaks well for its builders, who have evidently intended to make a lathe of exceptional productive capacity, and ability to stand up to the heavy duty now imposed on such tools

by the use of high-speed tool steels and coarse feeds for the rapid reduction of the material.

The head-stock is massive and of a symmetrically rounded form. The cone has five steps and takes a belt of rather more than the usual width. The spindle is of high carbon special steel and accurately ground, bored out with a large hole, and runs in a good quality of anti-friction metal boxes, provided with automatic ring oilers.

The carriage is proportionately heavy and strong, liberally provided with T-slots, and has a flat top for convenience of bolting down work to be bored or otherwise machined. The bearings upon the V's extend the entire length of the carriage. The compound

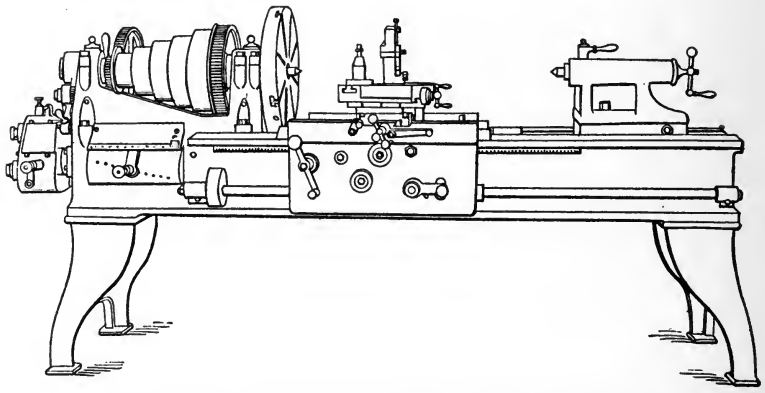


FIG. 248. — 20-inch Swing Engine Lathe built by the American Tool Works Company.

rest is broad and strong and well fitted with hand-scraped surfaces, as are all the sliding contacts of the lathe.

The bed is of deep box girder section. The webs are well tied together with cross bars of box form, making the bed very strong and rigid. It is of the "drop-V" pattern, which gives an additional swing of about $2\frac{1}{2}$ inches. The V's are far apart and the front tail-stock way is flat, which, in connection with the drop-V construction, renders it possible to add an unusual amount of metal to the bridge of the carriage, thus insuring unusual stiffness and rigidity.

The lead screw is located within the bed and imparts motion to the carriage directly under the cutting-tool. This construction

obviates much of the tendency to twist or lift the carriage off its seat so common in even the best modern lathes where the lead screw is located on the outside of the bed and pulls the carriage by its connection with the apron. The apron is tongued and grooved to the carriage and secured by large and substantial screws. All studs are of tool steel, hardened and ground. All pinions are of steel and are bushed with bronze. All gears are of wide face and coarse pitch. The reverse feeds are not by means of bevel gear and two bevel pinions, as in most modern lathes, but by tumbler gears, suitably controlled at the front of the apron. It is well known that bevel gears and pinions are broken by slipping in and out of engagement when running. In this lathe the bevel gear and pinions are constantly engaged, and therefore can be cut theoretically correct and run in close working contact. A separate splined rod is provided for driving the apron mechanism, thus obviating the necessity of splining the lead screw, as it is well known that no screw will remain true after splining. The screw is therefore simply and solely used for thread cutting and as a further precaution it is placed inside of the bed and has no connection whatever with the apron or its mechanism.

The carriage slides, both upper and lower, are fitted with taper gibs which are tongued and grooved into the sides, so that no amount of strain will disturb them. These gibs are adjusted by a convenient screw at each end. The feed screws are provided with micrometer dials.

The thread-cutting mechanism is exceptionally well made. All shafts are of high carbon steel and accurately ground. The four-speed gear box is mounted on the head end of the bed, and by means of clutch members, operated by suitable knobs conveniently located, four changes are instantly obtainable. This, in connection with a cone of eleven gears, mounted on the inside of the bed, any one of which can be engaged instantly by means of a sliding tumbler gear, makes forty four changes obtainable, without removing a gear. The index is well arranged and comparatively simple to understand, so that the practical operation of this mechanism is more simple and easy than many of the rapid change gear devices.

The workmanship on these lathes is unusually good, and this applies not only to the smoothness and fineness of finished surfaces,

but what is of still more importance, to good fits. That the makers have endeavored to make a particularly good lathe is evident, whatever may be our opinion of the design of the "disc of gears" introduced into the rapid change gear design.

The Springfield Machine Tool Company make a variety of engine lathes and special lathes for various purposes that are unique in some respects, and very serviceable lathes for a large class of manufacturing work.

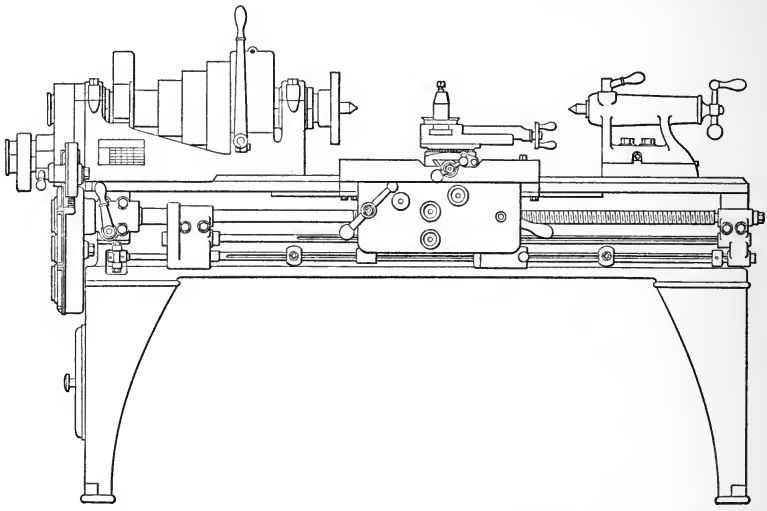


FIG. 249. — 16-inch Swing Engine Lathe built by the Springfield Machine Tool Company.

Their 16-inch engine lathe is shown in Fig. 249, which is equipped with rapid change gear device, reverse motion operated at the apron, automatic stop for turning and thread cutting, and provided with a friction-geared head spindle.

In Fig. 250 is given an end elevation of the lathe, principally for the purpose of showing the rapid change gear device, which is of the type first patented by Edward Flather in 1895, and since used to a considerable extent on small lathes built by various makers and under several later patents, most of which are modifications of that of Flather.

The main spindle is hollow and of hammered crucible steel, with large bearings running in self-oiling bronze boxes, and is friction-

geared in a similar manner to that of a screw machine or turret lathe, which is of considerable convenience in many classes of work.

The lead screw has a telescopically arranged extension, controlled by a hand lever. This extension of the lead screw is reduced at its end to enter the hole in the change-gear, a distance equal to its width, before the clutches with which the change-gears and extensions are fitted come in contact with each other. Thus, when one of the change-gears is connected with the lead screw it ceases to depend upon the disc for support, but is mounted on the lead screw as substantially as if secured by a nut and washer, although it is at other times supported by, and practically journaled in, the circular gear box. As a sufficient range of feeds or screw pitches cannot be obtained by changing gears on the lead screw, only provision is made at the head-stock for various ratios of speed. This is accomplished by means of three pairs of gears, contained in cases, and giving the ratios of 1 to 1, 2 to 1, and 4 to 1; and when the latter two are reversed, the ratios become 1 to 2, and 1 to 4, giving five rates of speed for the fixed pinion which engages with the intermediate gear, necessary for transmitting the motion to the gear on the lead screw.

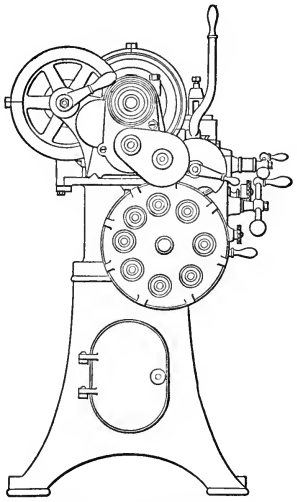


FIG. 250. — End Elevation of 16-inch Springfield Lathe.

As there is only one pair of gears that can be used at a time, a receptacle is formed in the leg of the lathe to receive the other pairs, one being suspended from a stud projecting from the rear of this cabinet, while the other is similarly placed on the inside of the door, rendering either equally available for use in a moment.

The range of threads which may be cut on this lathe is from 2 to 56 per inch, and the turning feeds from 8 to 224 per inch.

Every change required to cut any of the threads or to produce any of the feeds above given can be made while the lathe is in motion.

While the type of device for rapid changes in speeds and for

thread cutting may not appeal to those machinists who desire a strongly built and strongly geared mechanism, this lathe is still very useful on a large variety of small and medium sized work, of which there is usually a great quantity in the modern factory or machine shop devoted to this class of work,

The same company make various types of useful lathes, fixtures, and accessories that will be referred to under the proper headings later on in this book.

The Hamilton Machine Tool Company build a commendable line of engine lathes and seem to have aimed to build machines of

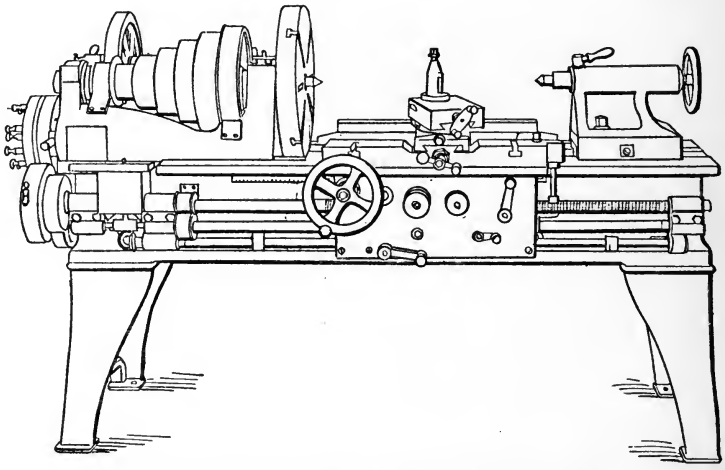


FIG. 251. — 18-inch Swing Engine Lathe built by the Hamilton Machine Tool Company.

good design and construction, combining the later features that are demanded by modern methods of machine shop and factory requirements for accurate and rapid work as well as a wide range of product.

The later designs of this company are heavy and rigid, yet with proper appreciation of the proportioning of the component parts, the machine does not have the clumsy or overloaded appearance sometimes seen in heavy lathes.

As a sample of their modern lathes their 18-inch swing engine lathe is shown in Fig. 251. The bed is deep and wide and well braced to resist strains. It is supported upon cabinets of modern

design, affording ample cubpoard room for storing tools and small parts. The pads for the lead screw, feed rod and reversing rod bearings are grooved and the bearings planed to fit them, thus assuring true and permanent alignment.

The head-stock is massive and of good design, insuring rigidity and preventing vibration and chatter even on the heaviest work which the lathe will be called upon to perform. The spindle is of high carbon steel forging and bored out $1\frac{3}{8}$ inches. It is ground its entire length and runs in phosphor bronze bearings, hand-scraped to fit the spindle. Anti-friction thrust bearings are provided with an adjusting nut for taking up lost motion due to wear. On this lathe these bearings are provided with hardened and ground steel washers. On the 22-inch swing and larger lathes these bearings are provided with hardened and ground-steel balls which are also adjustable and reduce the friction to a minimum, the ball-races being of tool steel and also hardened and ground.

The spindle cone has five steps, the largest being 12 inches diameter, and adapted for a $2\frac{3}{4}$-inch belt. Readily removable gear guards protect the face gear and the back gear from injury by chips, dirt, etc., and the operator from the danger sometimes resulting from these exposed parts.

The tail-stock is of the "offset" pattern, that is, cut away in front so as to permit the compound rest to swing around parallel to the V's of the lathe. The tail spindle is $2\frac{1}{16}$ inches in diameter, and is graduated for convenience in drilling. It is of steel and accurately ground and has an unusually long movement. The tail-stock has the usual set-over adjustment for turning tapers.

The carriage is massive and strong, and is gibbed at the front, back and *center*, and is scraped to a solid bearing upon the bed, throughout its entire length. It is entirely flat on top and amply provided with T-slots, so that work to be bored or otherwise machined can be as readily clamped upon it as upon the table of a planer or milling machine. The cross-feed screw has a micrometer attachment, by means of which, not only can turning and thread cutting be much facilitated, but the drilling of jigs and fixtures may be as readily done here as on a milling machine, so far as laying off accurate distances is concerned, by strapping the work to an angle-plate bolted down to the carriage.

In addition to the above feature, the lathe is provided with a rotating indicator or chasing dial, located on the top of the carriage, which enables the operator to catch the thread quickly and properly without reversing the forward motion of the lathe; and permitting him to return the carriage quickly to the starting-point by hand.

The compound rest is large and heavy with broad wearing surfaces accurately fitted by hand scraping, and provided with taper gibs. The swivel is graduated in degrees so that it can be quickly set at any required angle. The tool-post is formed from a solid steel bar and has a tool steel screw.

The apron is large and strong, and is fitted to the carriage by a tongue and groove. The operative parts are heavy and strong. The rod feed and the thread cutting by the lead screw are independent, and each, when in use, locks the other out of the possibility of becoming engaged, thus preventing the liability of breakage from this source. The feeds are driven by a powerful friction device and are readily reversible at the apron by a single movement.

An automatic stop is provided by the addition of a rod running the entire length of the bed, and which operates equally well when feeding in either direction. It operates with either the turning feed or with thread cutting, and enables the operator to chase up to a shoulder, by which feature it is very useful in cutting internal threads, or in boring to a certain fixed depth. It can also be set to prevent the carriage running against either the head-stock or tail-stock, and is therefore a safety device against the serious accidents that sometimes occur from this cause. This device is of great advantage in duplicating work such as the turning of shafts having one or several shoulders, as, the cut once fixed, the stop collar may be set and no further attention paid to the location of the shoulders than would be necessary in an automatic machine.

The quick change gear device by which a large number of threads of different pitches are cut, and by which a wide range of turning feeds are obtained, contains the "disc of gears" or circular case, containing eight change-gears and constructed upon the plan first invented and patented by Edward Flather in 1895. In addition to this device the usual multiplying gears are used, being contained in another case which properly protects them. This device is shown in the accompanying illustrations, in which Fig. 252 is an

end elevation and Fig. 253, a vertical, longitudinal section, showing the general design of the mechanism, which appears considerably complicated and hardly as strong as such a device ought to be in order to withstand the strains to which it is usually subjected, and therefore liable to get out of order. The device is well made and of good material, and will, no doubt, give as good results as may be expected from this form of rapid change gearing. It will cut 48 different threads from 1 to 56 per inch, and cutting-feeds from 6 to 336, all inclusive, by the use of three removable change-gears. The method by which the various changes are made is necessarily

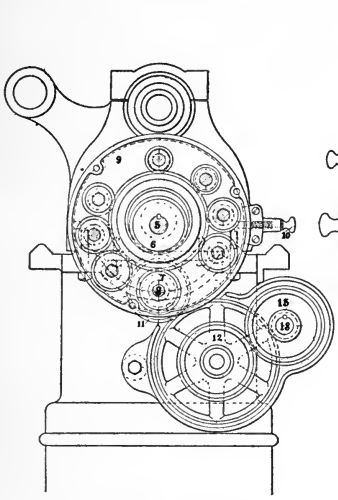


FIG. 252. — End Elevation of the 18-inch Hamilton Lathe.

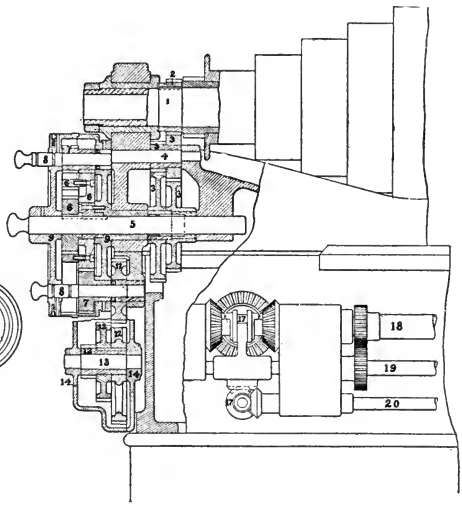


FIG. 253. — Longitudinal Section of Gearing of 18-inch Hamilton Lathe.

complicated, and in the hands of an inexperienced operator might lead to mistakes. This can be said of several of the similar devices built by other establishments.

The weight of the 18-inch swing by 8-foot bed lathe is 2,580 pounds, by which it will be seen that there has been no stinting of material in its design.

This company build a variety of lathes and attachments and accessories for the same, which are illustrated and described under appropriate headings later on in this book, and to which the reader is referred for information concerning them.

The W. P. Davis Machine Company make a general line of

plain engine lathes, of which a good example is shown of their 18-inch swing lathe in Fig. 254. The bed is of ample depth and well proportioned, and is supported on the older design of legs instead of cabinets.

The head-stock is of ample dimensions and has a crucible steel-forged spindle with a $1\frac{9}{32}$-inch hole through its entire length, and runs in phosphor bronze boxes, reamed and hand scraped. The front bearing is 3 inches in diameter and 5 inches long. The spindle cone has five steps, the largest being 11 inches in diameter and adapted for a $2\frac{1}{2}$-inch belt.

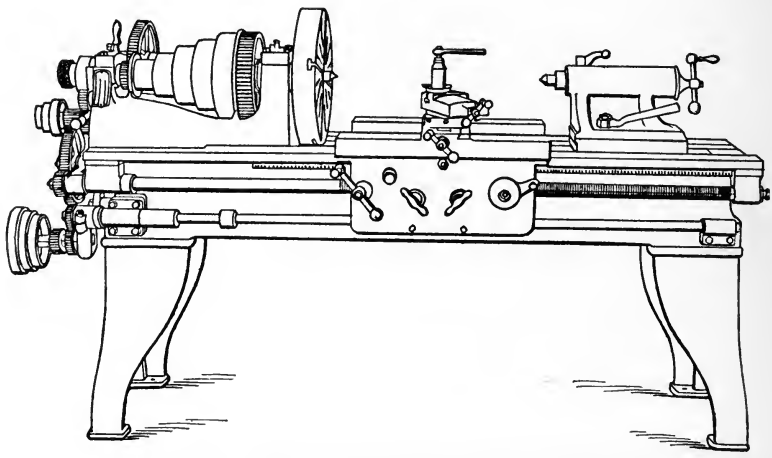


Fig. 254. — 18-inch Swing Engine Lathe, built by the W. P. Davis Machine Tool Company

The feed is belt-driven by the usual three-step cone, an arrangement for tightening the belt and multiplying gears whereby six different feeds may be obtained. The change-gears are such as will cut threads from 2 to 32 per inch inclusive.

The carriage, apron, tool-rests, etc., are of ample dimensions for the requisite strength. This lathe with an 8-foot bed weighs 2,460 pounds, a fair weight for a manufacturing lathe of these dimensions, which has evidently been the aim of the builders to produce.

The same firm make other types of lathes which are illustrated and described in future pages and under their appropriate headings. Some of them have special features to which the attention of the reader is particularly directed.

The Fosdick Machine Tool Company, better known as builders of radial drills, have recently commenced the construction of lathes also, and the one shown in Fig. 255 is entitled to special consideration as the aim of the makers evidently is to produce a lathe for practical use that will meet the demand for a good lathe at a reasonable price. This lathe is equipped, as illustrated, with feed box and with compound rest. The bed is made in different lengths from 6 to 12 feet, with cabinet or regular legs, and with or without oil pan. The spindle bearings are $2\frac{3}{4}$ and $2\frac{1}{8}$ inches diameter; there is a $1\frac{1}{4}$-inch hole through the spindle, and draw-in chucks are furnished

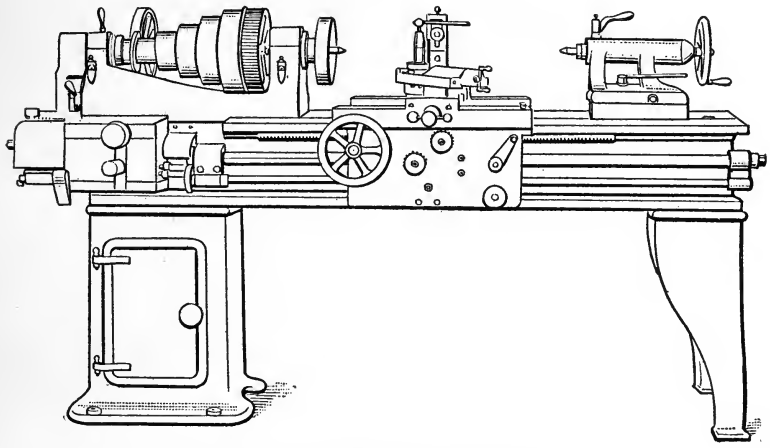


Fig. 255. — 16-inch Swing Engine Lathe built by the Fosdick Machine Tool Company.

when required. The bearings are bronze bushed throughout, and constant lubrication is afforded through an endless chain and large oil pockets. Owing to the design of the head, a three-step driving pulley may be used in place of the five-step cone, insuring a more powerful spindle drive when required for high-speed steel work.

The carriage has bearing surfaces of ample length and width on the shears, and the apron is of the box-section type, insuring strength and stiffness. The design of the tail-stock is clearly shown, and also that of the follow-rest. The compound rest is designed to receive a heavy tool-post. The compound feed box shown is the well-known Emmes device, giving forty changes, the screw-cutting

feeds ranging from 2 to 56 threads per inch, and the feeds for turning being just one fourth as coarse.

The taper attachment can be placed on any of the lathes without changing the bed or fitting it with brackets, and a turret of pentagon form, for the carriage, can be furnished when desired.

All screws on any part of the lathe requiring adjustment are operated with the tool-post wrench. The friction countershaft has self-oiling bearings and oil wells are formed in the friction pulleys.

The swing over bed is $16\frac{1}{4}$ inches, and over carriage $10\frac{1}{4}$ inches. With the 6-foot bed, the length taken between the centers is 34 inches. The width of the five-step cone pulley face is $2\frac{5}{8}$ inches, and of the three-step $3\frac{3}{8}$ inches. The countershaft speed with five-step cone is 120 revolutions per minute, and with three-step cone 250 revolutions per minute. The weight of the lathe with 6-foot bed is 2,000 pounds, which is ample for a lathe of these dimensions, and considerably above the average.

CHAPTER XVII

HEAVY LATHES

The Bradford Tool Company's 42-inch swing triple-geared engine lathe. The American Tool Works Company's 42-inch swing triple-geared engine lathe. The New Haven Manufacturing Company's 50-inch swing triple-geared engine lathe. The Niles Tool Works 72-inch swing triple-geared engine lathe. The Pond Machine Tool Company's 84-inch swing engine lathe.

THE 42-inch swing triple-geared lathe, built by the Bradford Machine Tool Company, is a good example of a well designed and massive lathe for the heaviest work to which a lathe of this character will be subjected. With the severe requirements of modern shop methods and the use of high-speed steels the problem confronting lathe builders has been one to tax their utmost energies in the way of good design scientifically and practically worked out; good materials lavishly applied; and good workmanship in every part. Without all of these in a marked degree a lathe may scarcely be classed as modern.

As to how well the designers and builders of the Bradford lathe have succeeded in their conditions is to a considerable extent manifest by an inspection of the illustration given in Fig. 256 and a study of the description which follows, as well as to some detailed engravings illustrating the special features of the machine.

The head-stock is long and massive, occupying over five feet on the head end of the bed, affording large housings for the spindle boxes and ample space for broad-faced, heavy back gears, and a five-step cone of from $10\frac{1}{2}$ to 22 inches in diameter and $5\frac{3}{8}$ inches face. The spindle is of crucible steel and is bored out with a 3-inch hole. It has a front bearing 6 inches in diameter and 10 inches long, and a rear bearing 5 inches in diameter and 9 inches long. The bearings are accurately ground and run in heavy bronze boxes, which are reamed and hand-scraped to a fix.

It was probably not an Irishman who wrote in the manufacturer's catalogue that "the back gears are conveniently located in front," however much it may sound like it, as it is a mechanical fact, and being so located applies the power at the proper point.

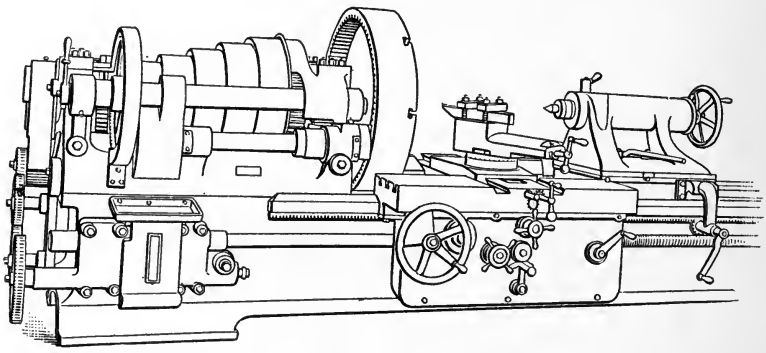


FIG. 256. — 48-inch Swing Engine Lathe built by the Bradford Machine Tool Company.

Being triple geared there are fifteen speeds, increasing in proper geometrical progression, and the lathe is provided with three rapid changes of feed for each speed.

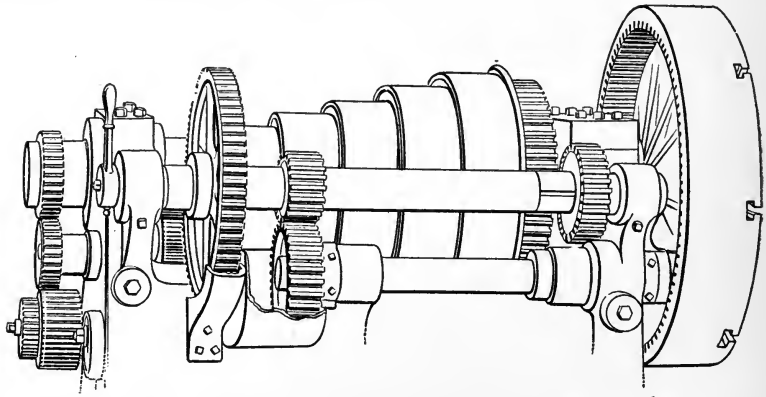


FIG. 257. — Head-Stock of the 48-inch Swing Bradford Lathe.

The coarse screw-cutting arrangement is shown at the left of the engraving, Fig. 257, and is a regular device on these lathes. It consists of a short intermediate shaft in the outer end of the head-stock, running in a sleeve adapted to be moved longitudinally. On each end of this shaft is fixed a spur gear, and when the shaft is

shifted to its outward position, the gear on the outer end of the lathe spindle communicates motion to the screw. When this shaft is at its inward position, motion is communicated from the cone gear in a ratio of 8 to 1. So that if the lathe is geared ordinarily to cut one thread per inch with the outer gears engaged, it will, with the inner gears engaged, cut a thread eight times as coarse, or one thread in 8 inches. In cutting very coarse threads the back gears are always used. Running in this manner the strain is taken off the change-gears, and threads or spirals as coarse as one turn in 16 inches can be cut.

In Fig. 258 is shown the nest of gears attached to the front of

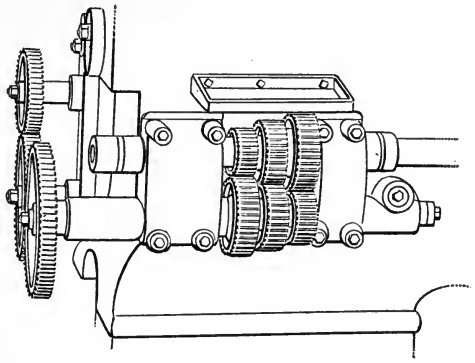


Fig. 258. — Lead Screw Gearing for the 48-inch Swing Bradford Lathe.

the bed. The three upper gears are fast to the lead screw, while the three lower gears are engaged consecutively by a sliding key, controlled by the nut shown at the right of the engraving, and handled by a wrench. These gears are of steel and may be engaged and disengaged while in motion.

The apron is massive and well constructed. A rear view of it is shown in Fig. 259, by which it will be seen that it is very simple, and therefore the parts may be made of ample strength. All shafts have bronze-bushed bearings. Independent frictions are used for both lateral and cross feeds, and are reversed from the front of the apron.

The lead screw is splined to drive the two bevel pinions, and its thread is only used when cutting threads. The halves of the lead

screw nut are operated by the usual form of cam, controlled by a lever shown at the right hand of the apron in the front view, as in Fig. 256. The end of the sliding rod which carries the forks for moving the bevel pinions is extended to the lead screw nut, where an attachment is made for locking the lead screw nut open whenever either bevel pinion is engaged with the driving bevel gear, and for locking both of these bevel pinions out of engagement whenever the lead screw nut is closed, thus preventing the two types of feed being thrown in at one time. The rack pinion is adapted to be withdrawn from engagement with the rack when thread cutting is being done.

The carriage is very long, deep, and massive, and is gibbed both front and back. It has a bearing of 48 inches on the V's, and is

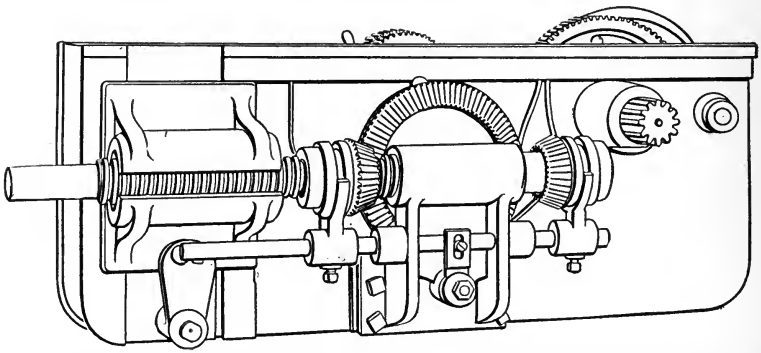


FIG. 259. — Rear View of Apron of the 48-inch Swing Bradford Lathe.

hand-scraped to an accurate fit. The inside V's of the bed are lower than the outside V's, by which construction the bridge of the carriage may be made much thicker and stronger, thus adding materially to the strength of the carriage at the point where it is usually the weakest.

The compound rest is large and broad, with an ample tool block with heavy tool clamping bars, and having an angular power feed of 12 inches in any direction. The base is graduated and both top and bottom slides are provided with taper gibs and adjusting screws.

The tail-stock is of ample dimensions with a bearing 26 inches long on the bed. The tail-stock spindle is $4\frac{1}{8}$ inches in diameter

and has a travel of 16 inches. It has the usual set-over screw for use in turning taper work, and is provided with a rack and pinion device for conveniently moving it to any desired point on the bed.

This lathe made with a 12-foot bed weighs 16,500 pounds, by which its massive design and great strength may be judged and by which the points stated in the opening sentences of this description may be more readily appreciated.

The American Tool Works Company have recently designed an excellent 42-inch swing lathe intended for heavy work and having a number of good features not usually found in lathes of this capacity. An illustration of this lathe is shown in Fig. 260, which gives a good idea of its massive design and symmetrical outline.

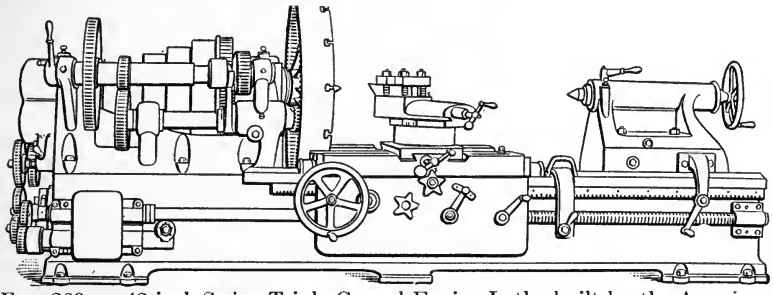


FIG. 260. — 42-inch Swing Triple-Geared Engine Lathe built by the American Tool Works Company.

The head-stock is large and massive with ample housings for the spindle boxes, which are of phosphor bronze carefully fitted to the high carbon hammered steel spindle, which is accurately ground and which carries a five-step cone. As the head is triple geared, this gives fifteen speeds arranged in correct geometrical progression.

The carriage is very heavy and strong, long bearing on the V's, and made with a flat top so as to be convenient for bolting down work to be bored. The compound rest is equally strong and provided with heavy clamping straps for holding down the tools.

The feed is driven through a quick change gear mechanism which provides thirty-two changes for feeding and thread cutting, the range of threads being from 1 thread in 4 inches to 16 threads per inch, including $11\frac{1}{2}$ pipe thread. The feed range is from 6.4 to 92 cuts per inch.

The device is operated while the machine is running, if necessary, by a revolving nut seen at the right of the gear box beneath the head, which moves a sliding key engaging two opposite gears, each being one of a cone of gears which is encased in the gear box. The feed or screw pitches thus obtained are multiplied by the compound gears on the quadrant at the end of the head, it being necessary to change one gear only on the quadrant for each additional thread.

This arrangement gives flexibility to the screw-cutting mechanism, making it possible to cut an unlimited number of sizes of threads or worms, either finer or coarser than the range indicated above. An index plate is provided to assist in obtaining the desired feed or pitch. The feed may be reversed in the apron, a feature which is valuable on a long lathe where the tool may be working at some distance from the head-stock.

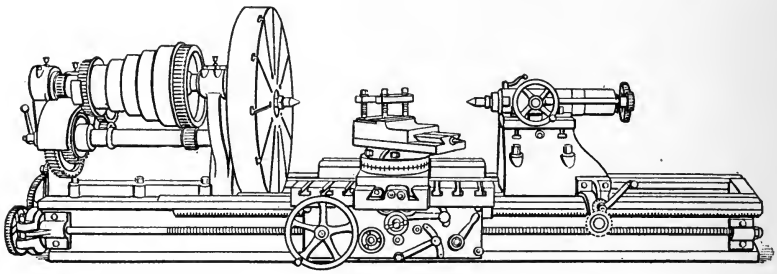


FIG. 261. — 50-inch Swing Triple-Geared Engine Lathe, built by the New Haven Manufacturing Company.

The New Haven Manufacturing Company build a 50-inch swing engine lathe that, while it is a comparatively plain and simple lathe, furnishes as good a tool at the price as any in the market. The effort has been made to build a very massive and substantial lathe without unnecessary complication or finish. This lathe is shown in Fig. 261.

The head-stock is very heavy and well designed, and carries a forged crucible steel spindle with a front bearing 8 inches in diameter and 12 inches long, and a rear bearing 6 inches in diameter and 9 inches long, and running in cast iron boxes lined with genuine babbitt metal that is peinned in, bored, reamed, and scraped. The driving-cone has five steps, ranging from $10\frac{3}{4}$ to $19\frac{3}{4}$ inches, and adapted for a 4-inch belt. The head is triple geared, giving

fifteen changes of speed. All the gears are broad and of coarse pitch, giving ample driving power. The face-plate is heavy and well ribbed, and keyed to the nose of the spindle, and has a broad-faced internal gear bolted to its rear side, from which it is driven by a steel pinion.

The tail-stock is constructed with a double set of holding-down bolts, by which means the upper bolts may be loosened and the tail center set over for turning tapers without blocking up the work or danger of its dropping out of the centers. The tail spindle is 5 inches in diameter and reamed for a No. 6 Morse taper. The operating hand wheel is directly in front of the operator and is back geared to the spindle in a ratio of 3 to 1, so as to be easily and conveniently operated. A back geared rack and pinion device permits the tail-stock to be easily moved to any desired position on the bed.

The carriage is very heavy and strong, gibbed front and back, with an unusually long bearing upon the bed, and carries a massive compound rest with a long angular feed in all directions, a graduated base and large hardened straps, supported by spiral springs upon studs, for holding the tool. These straps have projecting ends so that tools may be held outside of the studs, which may be placed either crosswise or lengthwise of the tool block as may be most convenient for the work being done.

The apron is built with double plates so as to give shafts and studs a bearing at each end. All feeds are reversible at the apron. A large bevel gear with two bevel pinions is provided in the apron, and an automatic locking mechanism prevents turning feeds and thread-cutting feed from being engaged at the same time. As an extra precaution against the frictions binding and refusing to release properly when a tool gets caught and in danger of breaking or spoiling work, as is liable to be the case on heavy work, or with very heavy cuts, an additional friction is provided as safety device, as the most careless operator is not liable to screw up *both* frictions beyond the point of releasing under an abnormally heavy strain, in case of an accident which might result in serious injury to the tool, the work, or the feeding mechanism in the apron.

The feed is positive, by a series of gears on the head-stock, with the usual change-gears for operating the lead screw, which is splined for driving the apron mechanism.

All sliding surfaces are hand scraped. Taper gibs, with adjusting screws, are used in the carriage and compound rest. The lead screw is made of special steel rolled for the purpose, $2\frac{7}{16}$ inches in diameter, and cut with 2 threads per inch. Pinions are of crucible steel and all nuts are case hardened. The countershaft has self-oiling boxes. The weight of the lathe with an 18-foot bed is 20,000 pounds, showing it to be a very massive machine for its capacity.

Prominent among the manufactures of heavy lathes is the Niles Tool Works who are also builders of heavy machine tools of other classes which have proven very popular on account of their good design, ample strength, generous proportions and excellent workmanship.

In Fig. 262 is shown one of their 72-inch swing lathes adapted

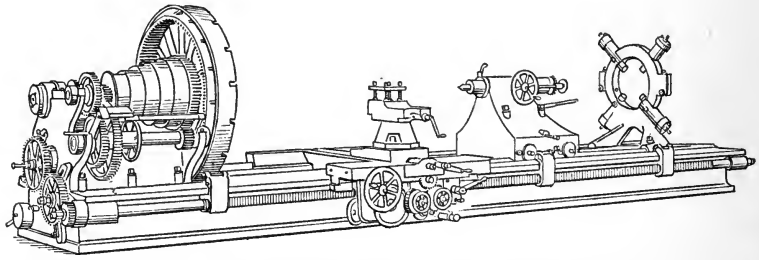


FIG. 262. — 72-inch Swing Triple-Geared Engine Lathe, built by the Niles-Bement Pond Company (usually called a Niles Lathe).

for heavy work. This lathe is of somewhat similar design to the 50-inch New Haven Lathe shown in Fig. 261, but considerably heavier, not only in proportion to its larger swing but as generally considered, a more massive machine.

The head spindle is very large and constructed of cast iron, as is usual with very large lathes. It is driven by means of the heavy internal gear on the face-plate only, as the cone runs upon a separate shaft provided for that purpose. The face-plate, which is very heavy and strongly braced by ample radial ribs on its rear side, is keyed to the head spindle and is not ordinarily removable.

The head-stock is triple geared by strong and heavy gears with wide faces. Thus fifteen speeds are provided for with ample space on the five-step cone for a wide driving belt.

The feeding and screw-cutting mechanism has three changes

in the head-stock by means of a sliding pin which handles the connecting devices of the change gearing. The lead screw drives the feeding mechanism without using the threads cut upon it, through the medium of a short feed rod, located in the apron. This method avoids the use of a long feed rod with its many supports and the attendant inconvenience which is of much greater moment than in those used for the much larger and heavier lead screw.

The bed is very broad and massive and furnishes ample support for the heavy head-stock and its weighty appendages, the long and broad carriage with its compound rest of ample proportion, and the massive tail-stock, as well as for the four-jawed center rest which is furnished with this lathe.

The tail-stock is broad and heavy and carries a large tail spindle, moved by a system of miter and spur-gearing operated by a large hand wheel at the front side, and within convenient reach of the operator. The tail-stock is secured to the bed by four heavy bolts and a pawl engaging in a rack, cast to the bed on the center line.

While the tail-stock is unusually heavy it can be readily moved along the bed upon friction wheels, which are easily put in contact with the bed by means of levers provided for that purpose. The usual set-over device is provided for turning tapers.

These builders make much larger lathes upon the same design, and also upon special designs adapted for making large guns, ingot slicing, machining large forgings such as crank-shafts and the like. Of this character they build lathes swinging 90, 100, 110, and 120 inches, and of any length of bed that may be required.

An excellent example of heavy lathes for handling large forgings such as crank-shafts and the heavier castings coming within the capacity of such a machine is the 84-inch swing lathe, built by the Pond Machine Tool Company, now operating in connection with the Niles Company. It is shown in Fig. 263. It really swings 86 inches over the V's and 67 inches over the carriage.

The lathe is designed with ample provision for the immense strains to which such a lathe is subjected. As will be seen by an examination of the engraving, the head-stock is unusually massive, with liberal dimensions of the housings for the front and rear boxes of the main spindle, which is a matter of prime importance in any lathe, and more particularly in one designed for very heavy work.

Attention is also called to the massive construction of the compound rest, which is much stronger and more rigid proportionally than that of the 72-inch swing lathe, built by the Niles Works and shown in Fig. 262.

The carriage has a very long bearing on the bed and is made deep and heavy, as should be the case with this type of lathe. An objectionable feature is that of locating apron gears in front of the apron rather than between the apron plates, out of the way of the operator and beyond the reach of ordinary accidental injury to themselves. This should be avoided as far as possible in all lathes.

The tail-stock is of massive and rigid design, and well adapted for the heavy work expected of the lathe. It is provided with the

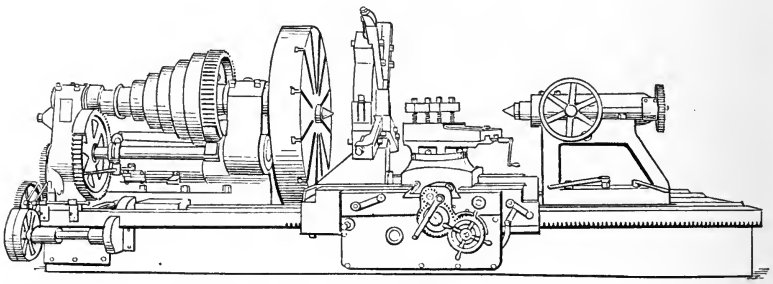


Fig. 263. — 82-inch Swing Triple-Geared Engine Lathe, built by the Niles-Bement-Pond Company (usually called a Pond Lathe).

geared device for moving the spindle, by which the hand wheel is placed at the front of the tail-stock and within easy reach of the operator. The base is secured to the bed by four bolts in the usual manner, while the dividing line between the base and the top casting carrying the spindle is placed high up and the top secured by four other bolts. By providing this double set of bolts the spindle may be set over for turning tapers by loosening the upper set of bolts only, leaving the main casting or base still firmly secured to the bed. Thus it is not necessary to block up or to remove the work from the lathe when setting for tapers, which is of considerable advantage, particularly on the heavy work which this lathe is designed to do.

In the builders' description of this lathe they say:

"With a 22-foot bed, this lathe will turn 8 feet 4 inches between

centers. All its spindles are mounted in bronze bearings. The head spindle has upon it a thick flange of large diameter to which the face-plate is bolted in addition to being forced on. The cone has six wide belt steps of large diameter. It is mounted on the face-plate pinion shaft, is back geared and geared in to an internal gear on the face-plate, giving twenty-four changes of speed. The sliding head has a set-over for taper turning, held independently by four bolts, thus allowing adjustment without unclamping from the bed. It is provided with a pawl engaging a rack in the bed and is easily moved by gearing engaging a steel rack.

"The bed has three wide tracks, with the lead screw between them, bringing the line of strain nearly central, and is sufficiently wide to support the tool slide without the latter overhanging its front side when turning the largest diameters. The carriage has long bearings on the bed, is gibbed to the outside edges, and can be clamped when cross-feeding. It is provided with a tool slide having compound and swiveling movements; also with screw-cutting attachment and automatic friction longitudinal, cross and angular feeds.

"If either of the feeds, screw-cutting attachment, or rapid traverse of carriage and tool slides by power is in use, it locks out all others. The direction of the feeds may be changed at the carriage. Screw-cutting attachment and feeds are connected to the head spindle by three gears and a sliding key, giving three changes without changing gears. The carriage gearing is driven by a spline in the steel lead screw. The thread of the lead screw is used only for screw cutting. The gear engaging the feed rack can be disengaged when cutting screws, thus preventing uneven motion, caused by the revolution of the feed gearing."

CHAPTER XVIII

HIGH-SPEED LATHES

Prentice Brothers Company's new high-speed, geared head lathe. A detailed description of its special features. A roughing lathe built by the R. K. Le Blond Machine Tool Company. Lodge & Shipley's patent head lathe. The prime requisities of a good lathe head. Description of the lathe in detail. The capacity of the lathe. A special turning lathe of 24-inch swing built by the F. E. Reed Company. A two-part head-stock. The special rest. Its two methods of operation. Its special countershaft. The Lo-swing lathe, built by the Fitchburg Machine Tool Works. Its peculiar design. A single purpose machine. An ideal machine for small work. Builders who have the courage of their conviction.

The Prentice Brothers Company have recently brought out a new high-speed geared head lathe, that possesses some valuable features and is worthy of careful consideration. It is well designed to meet all the most rigid demands of modern shop methods that may be made upon a lathe of this character, and is strongly built to withstand all the shocks and strains to which it may be subjected.

Apart from its great power, the machine is interesting mechanically in its arrangement for procuring eight spindle speeds from a single speed countershaft, thus always furnishing an equal belt power no matter what spindle speed is in use. It is also of much interest in that it presents a new modification of the quick change feed device.

The lathe is shown complete in Fig. 264, and the details of the head-stock, feed gears, and quick change gear mechanisms in Figs. 265, 266, 267, 268, 269, 270, and 271. A careful study of these details will be interesting as giving a clear insight into the prominent features of the device. As will be seen by referring to Fig. 265, four changes of speed are obtained between the pulley shaft and the spindle through an arrangement of gears and friction clutches,

and that the number of changes are doubled by engaging the back gears by means of a positive tooth clutch.

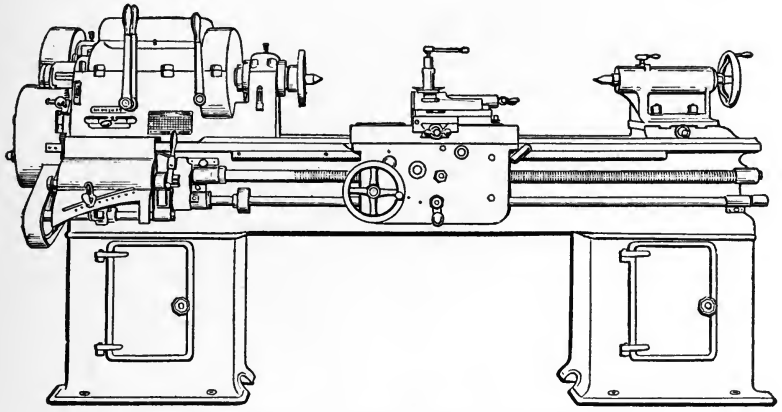


FIG. 264. — High-Speed Engine Lathe built by the Prentice Bros. Company.

The back gears never travel fast enough to render it impracticable to use a positive clutch for this purpose. The result is a ratio of 6 to 1 between the spindle and any friction while the back

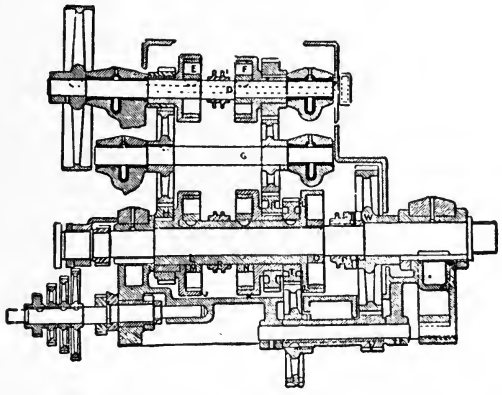


FIG. 265. — Horizontal Section of Head-Stock of Prentice High-Speed Lathe.

gears are in use. The driving pulley, which is located on a back shaft, drives the spindle by means of spur gearing. The pulley carries a 4-inch belt, which runs at a speed sufficient to transmit 15 horse power.

The eight changes of speed are obtained by means of the levers A, B, and C, shown in Figs. 266 and 267, and also at the front of the head-stock in Fig. 264. This arrangement of the several operative parts is such that there is no danger of engaging conflicting spindle speeds at the same time. On the pulley shaft D, in Fig. 265, which is situated at the back of the head-stock, and revolves at a constant speed at all times, are two friction clutches E and F, either of which may be operated by the lever A, which slides the friction spool I along the shaft D, for the purpose of engaging the clutches at the right or the left. Between the head spindle and the pulley shaft D is located a secondary shaft G, which carries two gears of different

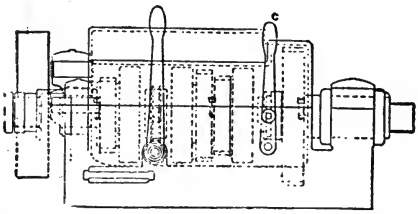


FIG. 266. — Front Elevation of Head-Stock of Prentice High-Speed Lathe.

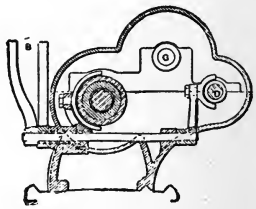


FIG. 267. — Cross Section of Head-Stock of Prentice High-Speed Lathe.

diameters, engaging with corresponding gears upon the pulley shaft D, and also gears which are fixed to the hubs of the friction discs J and K. These friction discs run loosely upon the quill L, L, which is itself loosely journaled upon the head spindle and which carries the friction disc L^1 at its end. The friction rings M, N, are keyed to the quill L. The friction ring O is keyed to the head spindle.

The four high-speeds are engaged as follows: With the frictions E, M, and O, driving directly; with the frictions F, N, and O, driving directly; with the frictions F, M, and O, driving through the intermediate shaft G; and with frictions E, N, and O, also through the intermediate shaft. The back gears and the spindle-driving gear W run constantly, while the friction spool I is engaged with either friction E or F. By engaging the friction spool and clutch P, which is keyed to the lathe spindle, with the spindle driving gear W, the back gear speeds are obtained. If desired, the lathe is furnished with a two-speed countershaft, to double the number of speeds to 16.

The device for changing the feed and for the cutting of screw threads is a radical change from the swing intermediate gear type, as it does away with the raising and lowering an intermediate gear sweep and sliding the intermediate gear laterally to engage with feed gears on the end of the head and bed. A pull spline and spring spline in combination replace the older mechanism.

Upon the end of the head-stock and in the position usually occupied by the regular feed spindle is a feed shaft, A, in Fig. 268, upon which four gears are splined. The shaft is supported at its outer end in a brass bushing mounted upon the gear guard. This shaft with its gears revolves at the same speed as the main head spindle of the lathe. Below the feed shaft is a hollow stud B, on which are loosely mounted four gears meshing with the feed gears on A. The gears on both A and B run constantly with the main spindle when not disengaged by the usual rocker device on the end of the head-stock at O.

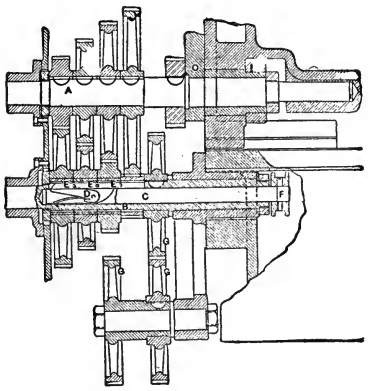


FIG. 268. — Vertical Section of Feed Gears of Prentice High-Speed Lathe.

The two groups of gears are of the ratio 2 to 1, 1 to 1, 1 to 2, and 1 to 4, which, in connection with the bank of gears mounted on the side of the head, gives a range of thread cutting from 2 to 32 per inch. The feed cuts per inch are 5.7 times the number of threads cut.

The hollow stud B contains a pull rod, C, which has fastened to its end the spring spline D. The spring spline allows changes of feed and thread cutting to be made instantly while the lathe is in motion, by sliding the handle E, Fig. 269, on its guide rod, the handle projecting from the side of the head-stock and connected with pull rod C, at F, in Fig. 268. The hollow shaft B contains a slot running the full width of the four gears.

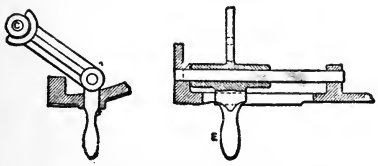


FIG. 269. — Change-Gear Levers of Prentice High-Speed Lathe.

When it is desired to change the rate of feed, the pull spline C being moved laterally causes the spring spline to be withdrawn from a slot in the bushing on the feed gear, throwing that gear out of use. When the spring spline passes the pin E it immediately engages the next gear. The form of the driving end of the spline makes this action against the pins possible.

The gears G, G, in Fig. 268, drive the gear H in Fig. 270, which is fastened to the shaft J, on which is mounted a yoke carrying a sliding intermediate gear, which engages with the several gears mounted on shaft K. There being 11 gears in this bank, 44 changes of feed are obtained. Sliding on the end of shaft K in Fig. 270 is the gear L, which by means of a handle on the front of the bed may be engaged with either gear M on the feed rod or gear N on the lead screw. This device is intended especially to preserve the lead screw for screw-cutting purposes, as a great deal of care is taken in the manufacture of these screws to have them accurate.

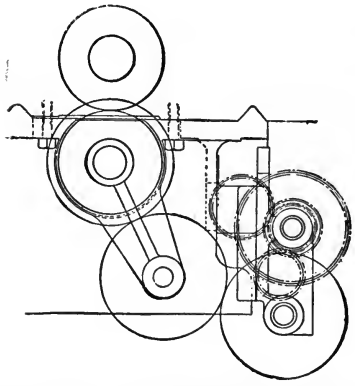


FIG. 270. — End Elevation of Gear-Connections of Prentice High-Speed Lathe.

The diagram shown in Fig. 271 is of an end view of the head-

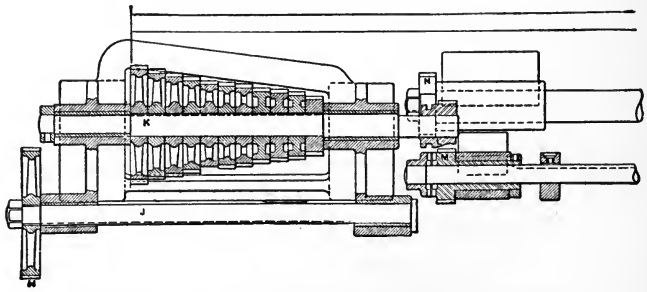


FIG. 271. — Diagram of Gear Connections of Prentice High-Speed Lathe.

stock, showing the gear connections from the head spindle to the cone of gears shown in section in Fig. 270, and is useful and inter-

esting in tracing the line of motion produced by these gears. The entire scheme of the head-stock and its operative parts is ingenious and a well-devised piece of mechanism.

A roughing lathe, built by the R. K. Le Blond Machine Tool Company, is shown in Fig. 272, and is principally interesting from the strength of its parts in proportion to the dimensions of the work that it will accommodate. This lathe is built of 18, 21 and 24-inch swing, and has an extra large spindle which runs in genuine babbitt metal bearings.

The carriage is much heavier than an ordinary engine lathe, and is extended out both back and front for additional bearing for tool rests. Of these there are two, one in front and the other at the

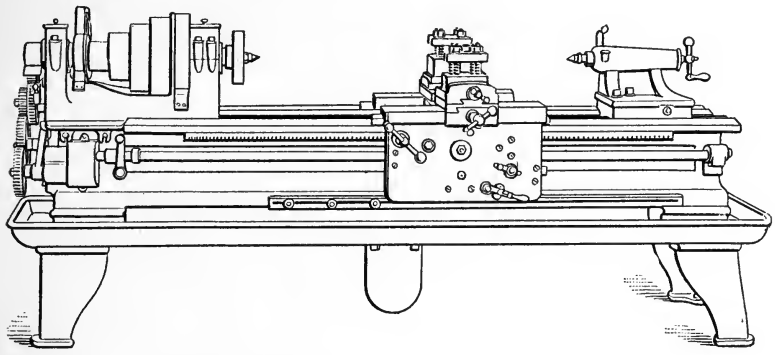


Fig. 272. — 18-inch Swing Roughing Lathe built by the R. K. Le Blond Machine Tool Company.

rear. The front tool rest has an extra movement in line with the slide. The back tool rest has an extra movement at right angles to the slide. Both of these are moved by a single screw moving towards or away from the center together.

The tail-stock is fastened to the bed with four large bolts, clamping it as far forward as possible. The feed is positive geared and is changed by means of lever shown in front of the bed, giving three changes, and can be stopped automatically at any point desired. By tripping it with a small handle on the front of the apron the carriage will proceed without removing the stop, and keep on until it comes in contact with the next stop.

The lathe is fitted with a geared oil pump for a continuous flow

of oil on the work; the pan is large enough to keep all dirt, oil, and chips from the floor. Countershaft has double friction pulleys.

This lathe is intended for heavy and rough work, as, for instance, rough turning forgings and heavy pieces of cut-off work that requires to be largely reduced in diameter with a heavy roughing cut. With the present low price of machine steel there is a good deal of the latter class of work to be done, and it can be done much more quickly and economically in a lathe of the class here shown than in the usual engine lathe, and its use saves the unnecessary wear when such work is done on the more expensive lathe.

Therefore the heavy roughing lathe is not only a saving in time and in money for doing the work, but also of the cost of tool equipment.

It was this idea that induced the design and construction of the so-called "rapid reduction lathes," which have come to be popular with manufacturers, not only on account of their economical expenses, but high efficiency.

Turret lathes are sometimes used in a similar manner, cutting off and roughing out the pieces from the bar stock, and are very efficient in doing this class of work. The first cost of these machines, however, is much more than that of the plain roughing lathe.

The Lodge & Shipley Machine Tool Company build a lathe with a head-stock that is a radical departure from the usual form of cone-driven lathes and which is entitled to special consideration. It is the result of much experimenting and is covered by patents. Commercially they call it their "Patent Head Lathe." It is an outcome of the recognition by the builders of the demand for a much more powerfully driven lathe for the use of modern high-speed lathe tools.

The manufacturer of the lathe says: "Our aim in its design has been to provide this power in such a manner that all the functions of the regular type would be retained, but the head would have wearing qualities, in addition, proportionate to the increased service expected of it. To this end we believe the observance of the following conditions to be of the highest importance: First, the spindle bearings, upon which the accuracy of the lathe is dependent, should not be subjected to the change of alignment by carrying the pull

of the belt. Second, more force at the cutting tool should be secured by the use of wider belts, instead of through higher gear ratios. Third, the possibility of running the lathe 'out of gear' should be provided for in cases where finishing cuts are desired. Fourth, speed changes should be secured without the necessity of shifting belts. Fifth, the lubrication of the bearings should be automatic and positive."

Doubtless every thoughtful mechanic will readily assent to these propositions as being self-evident.

Figure 273 shows the head-stock in place upon the bed and

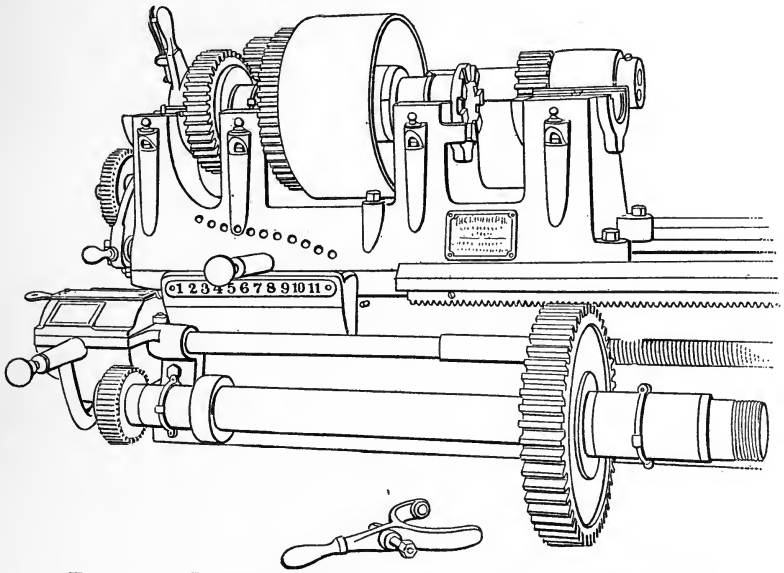


Fig. 273. — Head-Stock for Lodge & Shipley Patent Head Lathe.

with the main spindle and the gear covers removed in order to show the construction of the driving mechanism. Power is applied through a wide-faced pulley of large diameter which is keyed to a sleeve revolving in the two central bearings of the head-stock. At one end of this sleeve is a jaw clutch, and at the opposite end two gears of different diameters. The main spindle *passes through this sleeve without coming in contact with it,* having about an eighth of an inch clearance, and revolves in the two outer bearings, that is, the extreme front and the extreme rear bearing. It is connected to the

driving sleeve for direct belt speeds by the clutch, and for the back gear speeds through either back gear, according to the speed desired. A lever, convenient for the operator, engages or disengages the clutch.

As there is no contact between the driving sleeve and the spindle except through the clutch, the pull of the belt is all carried by the two central bearings. Sufficient clearance is provided in the clutch to prevent any of the belt strain being communicated through it to the spindle. The spindle bearings are thus relieved of all wear due to belt pull and their life greatly prolonged. By actual experiment with a 20-inch lathe it has been shown that the pressure exerted by a belt on spindle bearings was 17.6 pounds per square inch of bearing surface, while the total pressure exerted by the belt upon a spindle between bearings which effect the alignment of the spindle was 393 pounds. In the lathe under consideration this was entirely eliminated.

In the ordinary type of engine lathe the narrowness of the driving belt compels the use of the back gears for all cuts but the lightest ones, and on small diameters. To provide sufficient force at the tool for heavy cuts, this back gear ratio must necessarily be a high one, and, as the *speed* at which the cut is taken is reduced in the same ratio as *force* is gained, it is apparent that a heavy chip cannot be removed at a high speed unless the speed of the cone pulley is increased to an enormous rate. When this is done, the fact that it revolves directly on the spindle, where it is impracticable to maintain an adequate supply of oil, soon causes excessive friction and is liable to stick the cone pulley.

In the lathe we are considering the great width of belt used delivers sufficient force at the cutting-tool for heavy cuts through a comparatively low back gear ratio, in consequence of which the spindle speeds may be proportionately higher. An additional set of back gears of very low ratio is provided for cuts which are slightly beyond the capacity of the open belt, but which do not require the full force afforded by the high ratio. Thus it will be seen that high speeds can be secured through the back gears without the necessity of revolving the driving pulley at the enormous rate required of a cone pulley to perform the same work. In addition the construction of its bearings is such as to permit of perfect lubrication,

which has received a great deal of attention, and the manufacturers claim that the spindle will run a month with one oiling. Deep oil wells, holding about a pint each, are formed in the casting under the centers of the bearings of the spindle and driver sleeve, and are connected with gage glasses at the front of the head-stock for the purpose of showing the height of the oil. The oil wells are filled through these gage glasses, which allows any sediment or dirt which the oil may contain to settle to the bottom and not be deposited on the revolving journals where damage would be liable from cutting. At the center of each journal is attached a brass ring with four projections, on the principle of the bucket pump. As the journal revolves these buckets dip into the oil in the well, and, passing over the center of the bearing, pour the oil over the journal. Suitable ducts distribute the oil lengthwise of the bearing and return it to the well to be used again and again. This method provides a certain system of lubrication without regard to the speed of the revolving spindle.

The back gearing is designed with ratios to give a uniform progression of speed from the slowest to the fastest. The two back gears are connected to the back gear shaft by spline and key, and are easily moved lengthwise to engage with their respective gears on the driving sleeve. The back gear shaft and pinion are made of forged steel, thus insuring the requisite strength and wearing qualities. The journals for the shaft are placed at either end, where they revolve in bushings provided with oil reservoirs and the same system of oiling as that for the spindle and driving sleeve.

The end thrust of the spindle is against the rear housing of the head-stock by means of a large cast iron collar keyed fast to the spindle, between which and the faced inside of the housing are interposed two bronze washers placed on either side of a hardened steel washer of like diameter. This distributes the friction to four contacts, each composed of two dissimilar metals, and forming a very efficient device for the purpose.

A variable speed countershaft is provided for the lathe, by which a wide range of speeds may be obtained.

In Fig. 274 is shown a front elevation of this lathe with the gear covers removed so as to show the head-stock assembled and in running condition. The gear covers are of cast iron and cover

and protect all portions of the head-stock mechanism, except the wide-faced driving pulley. This will show the relative importance which a head-stock built according to this system holds to the other constituent parts of the machine. It also shows the very considerable added length necessary for the head-stock, and therefore the reduced length between centers when the same length of bed is considered.

But while the capacity of the lathe, so far as length between centers is concerned, is relatively much less, the real capacity of the lathe for producing work, *good* work, is so vastly increased that the production of this head may fairly be considered as adding

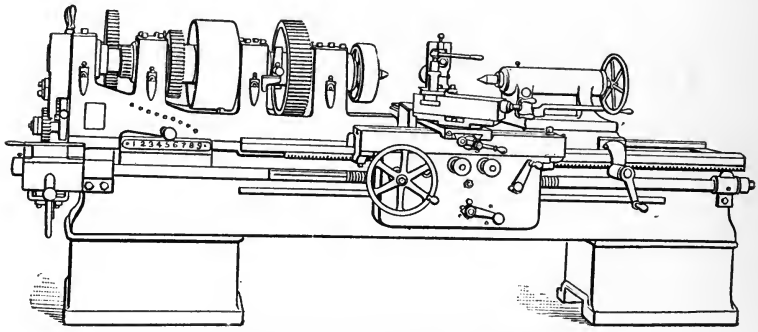


FIG. 274. — 22-inch Swing Patent Head Lathe, built by the Lodge & Shipley Machine Tool Company.

very much to the development of the lathe as a modern American machine shop tool.

A 24-inch special turning lathe is built by the F. E. Reed Company that is designed for reducing large amounts of metal at one turning, using the high-speed steel tools, and is an unusually stiff, strong, and powerful machine.

The head-stock is made in two parts to admit of a cone pulley as large as the lathe will swing over the bed. It has a large, forged steel spindle, the front bearing of which is $4\frac{1}{2}$ inches diameter by $9\frac{1}{2}$ inches long, and runs in babbitt lined bearings. The spindle is strongly back geared. The cone pulley has five sections, the largest of which is $20\frac{1}{2}$ inches diameter, driven by a $3\frac{1}{2}$-inch belt; then with the two friction pulleys on the countershaft this number of speeds can be doubled, making a total of twenty speeds which can be had

if desired. This lathe can be furnished with four-step cone for wider belt if desired.

A special feature of this lathe is the rest. It is provided with two patented elevating tool-posts, each having a universal tool-holder, in which any size of steel can be used to advantage, and so made that they admit of adjustment up and down while the tool is under cut. Each tool-post is moved from the front by a separate screw, and the rear tool-post is provided with a screw for adjustment crosswise of the rest. These tools can both be used to turn to the same diameter by dividing the chip; or, they can be used to reduce the diameter, removing large amounts of stock, working one tool in advance of the other, each tool turning to a different diameter.

A positive geared feed is provided, and so arranged that either a fine or a coarse feed can be obtained by means of the lever shown at the front of the lathe.

There are two methods of operation:

First. When it is desired to do rapid turning, and where it is not necessary to largely reduce the diameter, the front tool is brought up to the work and set so it will reduce the piece to the required diameter. Then the rear tool is adjusted to a point where it will turn to the same diameter as the front tool, after which it is adjusted by means of the cross adjusting screw so that it will divide the chip. Then by means of the small lever shown at front of lathe a coarser feed is engaged.

Second. When large reductions in diameter are desired, the front tool can be set to remove the required amount of stock, and the rear tool set to follow the front tool for removing a second large chip from a different or smaller diameter.

Arranged for either of the foregoing operations the lathe will turn off twice the amount of stock that can be removed at one turning in the ordinary 24-inch engine lathe, using the high-speed turning steels.

This lathe is set up with a pan and is provided with a pump and piping for ample lubrication of the cutting-tools.

The countershaft is furnished with two patent friction pulleys for two speeds, 200 and 250 revolutions per minute. These pulleys are 18 inches diameter and take a 5-inch belt. The pulleys are so arranged that they can be oiled while running, thereby saving loss of

time, danger, and annoyance in running off the belts, which is an important consideration where a number of lathes are in use. The countershaft is also furnished with self-oiling boxes.

This lathe is shown in Fig. 275, wherein its ample proportions and excellent design may be seen and appreciated. It is undoubtedly one of the best lathes of its kind, and for this particular and important use, now on the market. With a 10-foot bed this lathe weighs 7,390 pounds.

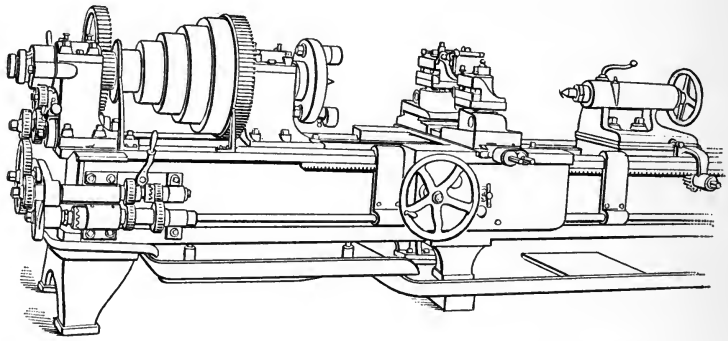


FIG. 275. — 24-inch Swing Special Turning Lathe, built by the F. E. Reed Company.

A special lathe has been brought out by the Fitchburg Machine Works at a comparatively recent date that is unique in construction in a number of ways, and for these reasons, as well as for its claim to a large production of work within a limited range, it is worthy of considerable attention.

It is called the "Lo-swing" lathe, and has a capacity from $\frac{1}{2}$ to $3\frac{1}{2}$ inches in diameter and up to 5 feet in length. The builders say: "We have purposely limited the range of work handled in order to increase productive capacity — a Lo-swing will do from three to four times as much work as an ordinary lathe in the same time.

"The extremely low swing and the single slide tool carriages, all four of which can be employed simultaneously, are distinguishing features of this machine, and the greater driving power, greater stability, the accurate control of tools and work, made possible by this construction, result in such rapid and economical production of work that the Lo-swing is already an acknowledged cost-reducer for the shop.

"The greater driving power, greater stability, the accurate control of tools and work, the low swing and small carriages, made possible by thus limiting the range, result in such rapid and economical production of work that the Lo-swing stands in the front rank as a cost reducer."

Figure 276 is a perspective view of this lathe, and gives a good idea of its general appearance. The aim of the builders is to so design the lathe as to limit its range of work so narrow as to make it "a single purpose" machine, that is, to confine its operations to one single class of work and then produce as much of that one class as possible.

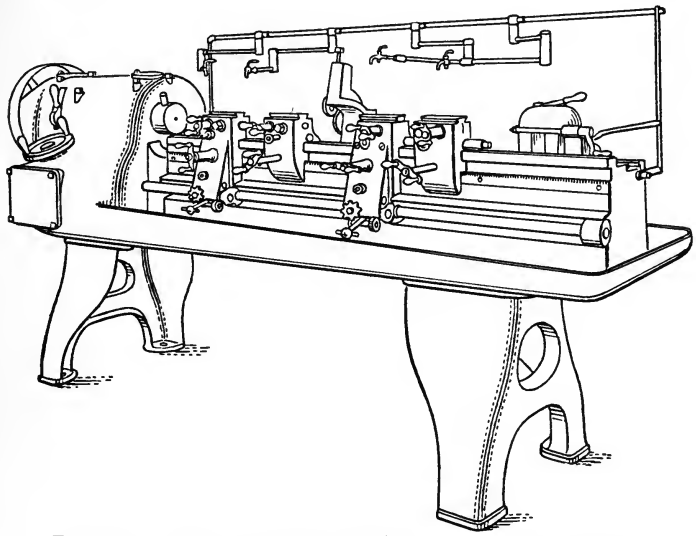


FIG. 276. — The "Lo-Swing" Lathe, built by the Fitchburg Machine Works.

Its two distinctive features are first, its very low swing, just enough to clear a $3\frac{1}{2}$-inch bar; and second, single tool slide carriages, several of which may be simultaneously employed.

The ideal machine for turning small work, which must be turned on centers, should have the tool mounted on a low rest with the guiding rail as close to the work as possible, and with the cross-feed screw located directly back of the cutting-tool so that a change of the screw would surely and positively effect a corresponding change in the position of the tool, and so that variation under working

strain from no load at all to a full load, or from a very light chip to a very heavy one, would have the least possible effect on the location of the tool.

While these conditions have been presented, time out of mind, by the mechanical engineers who have studied the lathe question and its relation to the regular lathes built and put on the market, the lathe builders have been slow to adopt such radical changes as would properly accomplish the required result.

The builders of the Lo-swing lathe have cut loose from the conservative methods of other lathe builders in producing this machine.

While it is yet too early to determine what will be the success of this venture, and how popular it may become with manufacturers requiring such a machine, it seems at this writing to have a bright future before it as a practical manufacturing machine, and its builders are certainly entitled to considerable credit for having the courage of their convictions in bringing it out.

CHAPTER XIX

SPECIAL LATHES

The F. E. Reed turret-head chucking lathe. Its special features. A useful turning rest. The Springfield Machine Tool Company's shaft-turning lathe. The three-tool shafting rest. The driving mechanism, Lubrication of the work. The principal dimensions. Fay & Scott's extension gap lathe. Details of its design. McCabe's double-spindle lathe. Its general features. Its various sizes. Pulley-turning lathe built by the New Haven Manufacturing Company. A special crowning device. Its general design. A defect in design. The omission of a valuable feature. Pulley-turning lathe built by the Niles Tool Works. A pulley-turning machine. Its general construction. Turning angular work. Convenience of a bench lathe. The Waltham Machine Company's bench lathe. Its general dimensions and special features. A grinding and a milling machine attachment. Devising special attachments. Reed's 10-inch swing wood-turning lathe. Special features of design. Popularity and endurance. The countershaft. Inverted V's.

The F. E. Reed Company build a number of sizes of turret head chucking lathes, with both plain and back-geared head-stocks, and cylindrical turrets placed upon a lateral top slide supported by a heavy base or bottom slide fitted to the V's of the bed.

In Fig. 277 is shown one of these lathes with a back-geared head-stock. The spindle, which is of crucible steel, is bored out to 2 inches and has a front bearing 4 inches in diameter. It is fitted with a three-step cone, the diameters of which are $7\frac{3}{4}$, 11, and 14 inches and carries a $3\frac{1}{2}$-inch belt.

The turret is 12 inches in diameter and has four holes, 2 inches diameter. It is arranged to be turned by hand, although, of course, may be made automatic in its action if desired. The turret slide is 38 inches long and has a movement of 17 inches, with an automatic feed and stop device. The turret shoe or bottom slide is 26 inches long.

The patented rest is a special feature. It is hinged to a slide which is bolted to the back side of bed, and adjustable for any length of work. It carries bushing for holding chuck drills, and is arranged to be turned back out of the way instantly to allow the use of other tools in the turret. This is a strong, powerful lathe, and with the builders system of three-lip drills and reamers, fully one third more holes can be made than with ordinary turret chuck lathes.

The lathe is built heavy and strong and the parts are well fitted and of good material, so as to stand the hard and continuous service to which such a machine is subjected, as well as the neglect and the

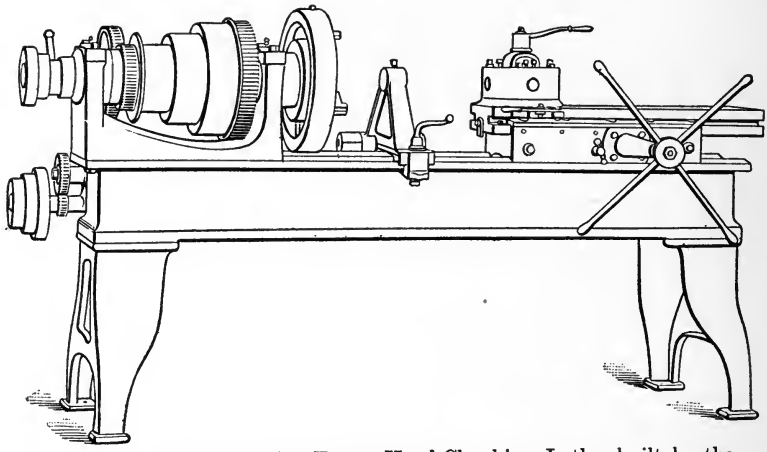


FIG. 277. — 20-inch Swing Turret Head Chucking Lathe, built by the F. E. Reed Company.

dirt and sand incidental to chucking work on rough castings. With a $7\frac{1}{2}$-foot bed the lathe weighs 2,750 pounds.

The turning of shafting requires not only a specially designed tool carriage, carrying three tools, but there should be a special arrangement of the feeding mechanism, specially long centers, and special devices for supporting the long shafts near the cutting-tools as they are being turned. These conditions have been considered and provided for in the 24-inch swing shafting lathe, built by the Springfield Machine Tool Company, which is shown in Fig. 278.

The three-tool shafting rest takes the place of the usual compound rest, and when in place connects the gear upon its oil pump

shaft to a similar gear on the driving shaft running the entire length of the bed. In designing the three-tool rest, two of the tools are placed on the left and one tool on the right of a massive follow rest. All of these tools are on the front side of the shaft to be turned, in which position they are convenient to manipulate and their cutting edges are always in plain sight. Some builders put one of these tools in a reversed position in the rear of the shaft, to be turned so as to balance the cutting strains better.

There is a driving mechanism arranged at the tail-stock as well as the head-stock, which is very convenient when turning shafts very long in proportion to their diameter, and hence subject to unusual torsional strains. Either of these drives may be thrown into gear instantly. Thus in turning a long, slim shaft, that half

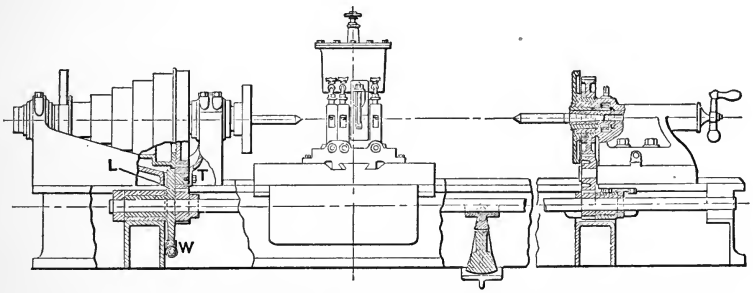


Fig. 278. — 24-inch Swing Shaft Turning Lathe, built by the Springfield Machine Tool Company.

near the tail-stock may be turned with the tail-stock driving mechanism. As the tools pass the center of the shaft the tail-stock drive is thrown out of gear and the head-stock drive engaged, The saving of time by having the drive applied near the point of resistance to the cutting tools should be considerable on long work.

Attention is called to the substantial manner in which the tail-stock spindle is clamped in order to render it suitable for supporting the driving mechanism, and also for furnishing a large wearing surface for the supplemental face-plate and face gear upon the body of the tail-stock.

The method used for guiding the shaft in the follow rest is to pass it through a split cylindrical collar, one of which is furnished for each diameter of shaft to be turned. These collars are broad

enough to furnish sufficient bearing surface to the shaft to prevent undue friction or cutting, while they hold the shaft accurately in place and can be closed up with an adjusting screw to compensate for any wear that may occur by continued use.

As a copious supply of lubricant is essential in shaft turning, a duplex single-acting plunger force pump is bolted under the water reservoir of the shafting rest, from which it receives its supply. Water is forced up into a tank sufficiently elevated to bring the supply tubes to the proper height above the cutting-tools. This tank is arranged with an automatic relief valve susceptible of adjustment so that any desired pressure can be obtained. By this arrangement the operator need not give any attention to the pump when he starts up the lathe, inasmuch as it provides automatically for the overflow should no water be required. The water used may have added to it soda, soap, or any of the usual ingredients used for such purposes.

On this lathe, when arranged as above, it is only necessary to remove the shafting rest, replace the compound rest, disconnect the tumbler gear under the head-stock, and the lathe is ready to perform any of the ordinary functions of an engine lathe, thus making it a valuable convertible lathe where there is not shaft-turning work to keep it going all the time, although that is the primary object in designing it and that is supposed to be its chief function.

The long centers shown are necessary as they must reach through the bushing in the shafting rest, which is mainly depended upon to support the shaft during the process of turning. They are bored and reamed to the diameter which the shaft is turned by the second tool (the first tool being a roughing tool), and then split so that by a little compression, exerted by a set screw provided for that purpose, the bushing is held in position and the shaft is accurately supported in its proper place.

Some of the principal dimensions of this lathe are as follows: Front bearing of main spindle, 4 inches in diameter and 7 inches long. Hole through the spindle, $1\frac{1}{2}$ inches. The driving cone has five steps, the largest of which is 16 inches in diameter and adapted for a $3\frac{1}{2}$-inch belt. The ratio of the back gearing is 12 to 1. The feeds are from 4 to 65 per inch. The lathe turns shafting up to 5 inches in diameter. Five feet of the length of the bed is occupied

by the head-stock and tail-stock. The tail-stock spindle is $2\frac{3}{4}$ inches in diameter and has a travel of 9 inches.

This lathe with a 35-foot bed (to take 30 feet between centers) weighs, 13,000, pounds, showing its substantial construction and ability to handle heavy shafting successfully.

Fay & Scott are the builders of an extension gap lathe which has the advantage over a lathe whose bed is cast with a fixed distance in the width of the gap, as shown in Fig. 23. In this case there is a base or lower bed, as shown in Fig. 279, upon which the bed proper, or upper portion, is mounted and upon which it slides.

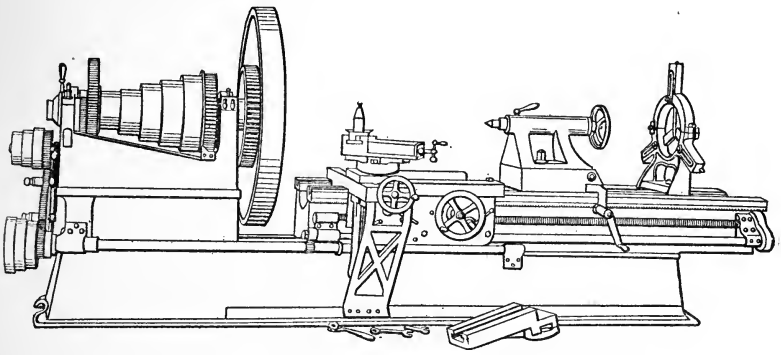


Fig. 279. — The Fay & Scott Extension Gap Lathe.

By this arrangement the "gap" can be widened to any distance desired, or it can be closed up entirely, converting it into an ordinary lathe. This is a great convenience on heavy work, particularly in a jobbing shop, or in any shop where there is a great variety of work to be done upon which large diameters occur, as the fly-wheels on crank shafts, large pulleys, and similar work.

The lathe is triple geared direct to the face-plate, the triple gear ratio being 34 to 1. The carriage is extended for turning work the full swing of the lathe, and is supported by an angle bracket with an adjustable gib on the lower bed. The lathe swings over the bed 28 inches, and through the gap 52 inches.

The 12-foot lathe takes $6\frac{1}{2}$ feet between centers when closed, and $10\frac{1}{2}$ feet when extended. The gap opens 4 feet, and every additional foot of bed lengthens the gap 6 inches.

Whatever may be the opinion as to the advisability of building

a lathe with two spindles for the purpose of furnishing a lathe of large and small capacity, the fact still remains that the two-spindle lathe, brought out a number of years ago by J. J. McCabe, has achieved a notable commercial success and many of them are in use.

An illustration of the 26–48 inch swing lathe of this construction is shown in Fig. 280, which gives an excellent idea of this machine.

It is impossible in a lathe of this character to so design it that it shall present a symmetrical contour, however we may view the matter, yet it seems as if the tail-stock of this lathe might be somewhat improved in its outlines without detracting from its strength or usefulness.

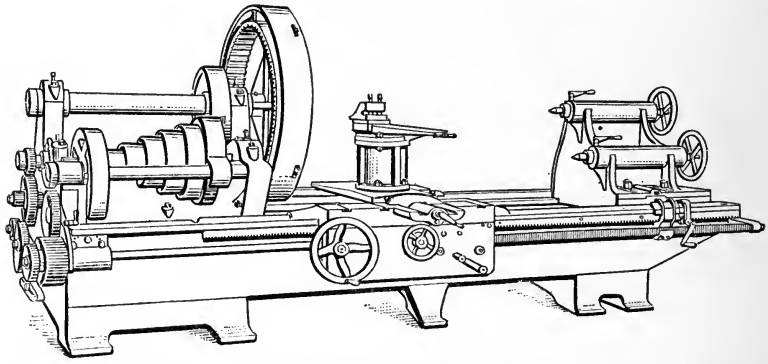


FIG. 280. — 26-48 inch Swing Double Spindle Lathe, built by J. J. McCabe.

The lathe has a deep and strong bed and is well supported by cabinet legs, the one under the tail-stock being arranged to swivel to fit an uneven floor. The head-stock might be somewhat stronger to advantage, particularly for the 48-inch swing spindle, but it is probably a fact that the large swing feature is more in use for boring and similar work than for heavy work requiring the full swing. Still we know personally that much large and heavy work is done on these lathes, and that in shops where such work is an exception rather than the general rule the lathe proves a valuable addition to the equipment, saving the expense of a large lathe which, under ordinary circumstances, would be engaged on useful work only a fraction of the time.

While the head-stock and tail-stock are ready at all times for

either the small or large swing, requiring only the necessary changing of face-plates to suit the work, the compound rest and the center rest require the use of a building-up or blocking piece when the change from small to large swing is made, and vice versa. Naturally the compound rest will not be as stiff and rigid as that of a regular 48-inch swing lathe, as the compound rest proper is designed upon lines and with dimensions that appear to be a compromise between those of a 26-inch and a 48-inch swing lathe.

The carriage has long bearings upon the bed and is of ample strength, as is also the apron and its operative parts. The feed is geared and consequently positive and capable of the necessary changes expected in a lathe of this character.

The head-stock cone is of five steps and takes a $3\frac{1}{2}$-inch belt. The head-stock is arranged with four adjusting screws, by means of which it may be at any time lined up parallel with the ways of the lathe. The head-stock and the tail-stock fit on flat surfaces instead of V's, thus increasing the normal swing of the lathe without raising the head spindle, as the inside V's are omitted. The tail-stock is fitted with a gib on the front side for the purpose of taking up any wear that will in time take place, and is provided with the usual set-over screw for turning taper work.

The upper spindle is triple geared and has double the ratio of back gearing of the lower spindle, while the internal geared face-plate shown in the engraving is furnished as an extra and gives a ratio of 72 to 1, giving ample power for large work.

This lathe is also made 24–40 inch, and 26–44 inch swing, while the one here illustrated and described is also furnished with permanent raising blocks or built up solid to swing 32–54 inches. It is also arranged to run with an electric motor when this method of driving is preferred.

A pulley turning and boring lathe is shown in Fig. 281, and is built by the New Haven Manufacturing Company. There are several features in this lathe which make it of unusual value, not only for turning and boring pulleys, but for a variety of very useful work.

Among these are the following: The compound rest has an unusually long lateral feed. It may be set at any desired angle and has a power feed, and also a hand feed from either end. The

compound rest screw may be disengaged by lifting a latch lever and the crowning attachment brought into operation.

Ordinarily the crowning of a pulley is effected by making its two parts with *straight* lines, leaving the angle of intersection of these lines in the middle of the face of the pulley. While this answers the purpose on ordinary pulleys, or pulleys with comparatively narrow faces, it is manifestly incorrect.

In this lathe the movement of the tool is controlled by a "former" A, attached to the fixed part of the compound rest and having a curved slot of proper radius in which the friction roll of a lever B travels. This lever is pivoted to the compound rest slide and

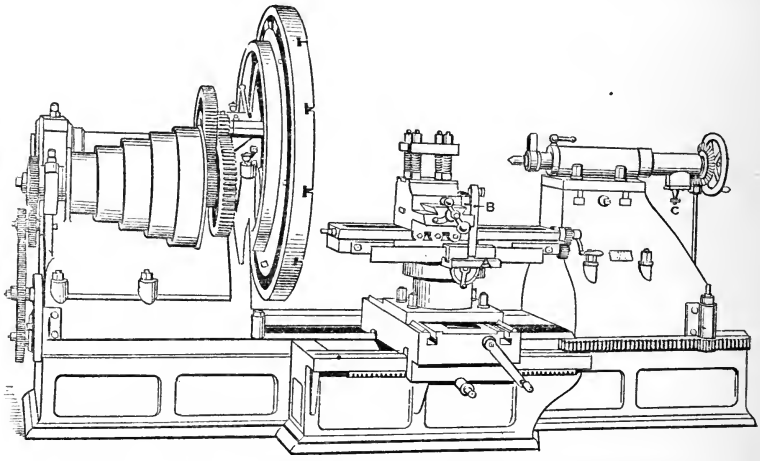


FIG. 281. — 60-inch Swing Pulley Lathe, built by the New Haven Manufacturing Company.

its upper end connected to the compound rest tool block by a connecting bar which thus controls the movement of the cutting-tool. Several of these grooved formers, of different radii, are furnished with the lathe for use with pulleys of different widths of face.

Another feature of this lathe is the automatic feed to the tail-stock spindle for boring purposes. This feed is of 13 inches travel, and readily thrown in and out by turning the knob C. In boring pulleys the proper boring bar is selected, one end placed in the taper hole in the tail spindle and secured by the clamp dog shown on the end of the spindle. The opposite end of this boring bar fits in a bushing in the head spindle, thus assuring a correct and properly

aligned hole. While this work is being done the pulley may be held in a chuck, or chuck jaws attached to the face-plate, by the hub or by the rim. The pulley having been bored is pressed on an arbor and supported on centers. It is driven by two arms secured by bolts to the face-plate in the usual manner.

The tail-stock is provided with the usual set-over, the same as in an ordinary engine lathe, for the purpose of turning tapers. It is provided with two sets of holding-down bolts so that the top casting with the spindle may be set over without detaching the tail-stock from the bed. By this means there is no necessity for removing the work from the lathe or blocking it up.

The head spindle is driven entirely by means of the internal gear bolted to the back of the face-plate through a pinion on the cone shaft. Back gearing is provided by which, with the five-step driving cone, ten speeds may be produced. A defect in the design of this back gearing is that the gears are journaled upon a stud supported at only one end, thus permitting considerable vibration, which is liable to show by producing chattering of the tool upon the work.

While the feed is entirely gear driven, provision is made for accidents to the tool by making the gear upon the end of the cone shaft with a friction device, by which it will be allowed to slip if heavy and unusual strain is brought upon it, rather than that the gear teeth be endangered.

This lathe is not of new design, but has been built in substantially its present form for many years; it is a deservedly popular machine.

The ordinary length of the bed of this lathe is about 11 feet. It swings 60 inches over the bed and 50 inches over the carriage and will take in 50 inches between centers. Its weight is about 10,000 pounds.

The head spindle is bored out so that boring bars of any length may be used. It will bore and turn pulleys up to 60 inches in diameter and 19 inches face, and a pulley up to 50 inches in diameter and 32 inches face.

By throwing out the back gears a fast boring speed is produced, or the boring and turning may proceed simultanously, if the pulley is held by the arms on a proper face-plate fixture.

There is no arrangement for the employment of a back tool which might do the roughing work. This fact necessarily limits needlessly the output of the lathe, as a proper rest for one or more back tools could be readily and economically provided.

A pulley-turning lathe may be so designed as to become rather a pulley-turning machine than a lathe proper, and when thus specialized will usually be a more efficient machine than if designed strictly on the lines of a lathe. Such a machine is shown in Fig. 282, which is built by the Niles Tool Works, who build these machines for turning pulleys of 30, 50, and 60 inches diameter.

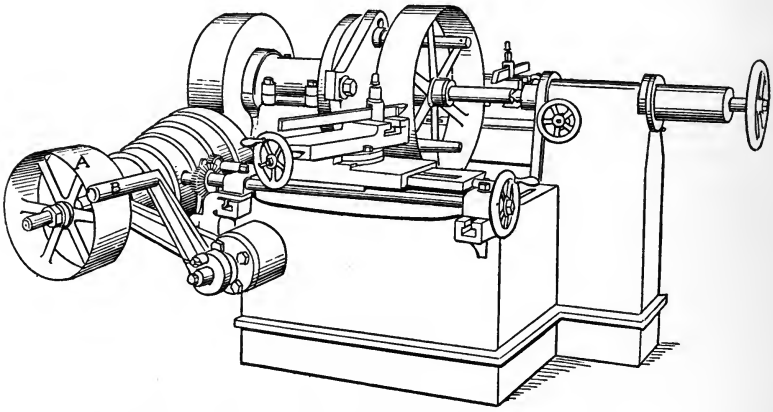


Fig. 282. — 40-inch Swing Pulley Turning Lathe, built by the Niles-Bement-Pond Company.

The bed, head-stock and tail-stock are all cast in one piece, and this casting extends to the floor or foundation and provides a very rigid support for the operative mechanism of the machine.

The head spindle is driven by spiral or tangent gearing, giving a very steady movement entirely devoid of the tendency to chatter as when turning a pulley or other light-rimmed wheel, when the power is by the usual spur gearing. By this device a much heavier cut, or a cut at a much coarser feed, may be successfully carried and consequently the time of performing the operation much reduced.

The pulley to be turned is forced on a mandrel or arbor and held between centers in the usual way for obtaining good concentric work. As to the method of driving the pulley, there is an equaliz-

ing face-plate which has arms projecting between the spokes or arms of the pulley near the rim, and which press equally upon opposite sides of the work so that there is no tendency to spring the pulley out of its proper shape, as is the case when it is held in a chuck.

There are two tool-rests which operate at the same time, one being in front and provided with an angular feed for crowning the face of the pulley, and one in the rear carrying an inverted tool and provided with a hand cross feed. This lathe tool takes the roughing cut while the front tool carries the finishing cut and crowns the pulley. The angular feed with which the front tool is provided adapts it for turning bevel gears as well as pulleys. When set to make a straight cut parallel to the axis of the work it is well adapted to turning the outside of large gear blanks, balance-wheels, and similar work.

While the tool at the rear of the machine is often set for a straight cut, parallel to the axis of the work, it is also provided with an adjustable slide by which it may be set at an angle for crowning the face of a pulley or for turning bevel gears and similar work. This feature is necesary in heavy work particularly, in order to leave an equal amount of metal to be cut away by the front tool during its entire cut.

The driving cone is of ample diameter; it is arranged in six steps and carries a very wide belt. It runs at a proper speed for polishing pulleys, as well as for driving the machine for turning purposes, and its shaft extends to the front as an arbor or mandrel upon which the pulley to be polished may be mounted as shown at A, Fig. 282. A convenient polishing rest is shown at B, which is used for this purpose.

This machine is not intended for boring the pulleys, this part of the work being much more expeditiously performed on a chucking lathe or similar machine, which may be run at a much higher speed for this purpose.

It frequently happens that small work and that which must be very true and correct, particularly in tool, model, and experimental work, a comparatively light *bench lathe* is much more convenient, useful and efficient than a floor machine of similar capacity. One or more of these lathes, of good design and construction, should form a part of the equipment of every tool room, and of any room

in a general machine shop or manufacturing plant where small work is done.

Such a bench lathe, built by the Waltham Machine Works, is shown in Fig. 283, and which is a good example of the best grade of American made bench lathe.

The bed of the lathe is 32 inches long and has a T-groove planed the entire length of the back side. A bed without this groove will be furnished, if desired, at a lower price, but such a bed will not take all the attachments that have been designed for it. The amount of metal in the bed is distributed so as to give great stability and rigidity while at the same time pleasing outlines are presented. These qualities apply equally to other parts of the lathe, beauty of design being one of its features.

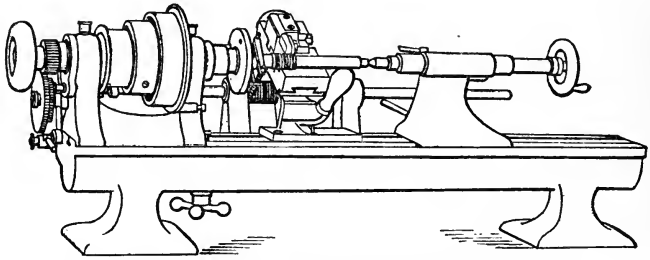


FIG. 283. — 8-inch Swing Bench Lathe built by the Waltham Watch Tool Company.

The head-stock will swing 8 inches. It has a hardened steel spindle and bearings, carefully ground and run together. It is very smooth running and the finest work can be done with it. The pulley has three steps of 3, 4, and 5 inches in diameter and will take a belt $1\frac{1}{8}$ inches wide. The larger flange has three circles of index holes, the numbers being 48, 60 and 100. The spindle is adapted to take split chucks of the most approved pattern, which will take wire up to $\frac{5}{8}$ inch in diameter through its entire length.

The spindle of the tail-stock passes entirely through the casting, so that whatever its position it always has its full bearing ($6\frac{3}{8}$ inches). It is graduated to tenths of an inch, while the gradations on the hand wheel read to 1-200 inch. The front side of the casting is cut away to give more room for the slide-rest. By this means the lathe can be used closer to the center than would other-

wise be the case. The back side of the casting is reinforced to give the necessary stiffness.

The base of the slide-rest rests directly upon the bed of the lathe, and its squaring device has a bearing on the front of the bed, below the lowest part of the head-stock and tail-stock. This gives the opportunity to make a long squaring device, thus insuring greater accuracy, and also to have the bearing where there is less liability of trouble from chips, dirt, etc. The builders also make a swivel squaring device by means of which angles can be turned or ground with the cross slide, thus enabling one to make two angles with one setting of the slide-rest. This is a valuable feature in making special cutters or mills, or in grinding spindles and bearings having two angles.

The feed screws have hardened bearings, and are provided with indices that are graduated to read to 1-1000 inch on the swivel screw, and to 1-2000 inch on the cross-slide screw, the latter division being adapted so that the movement of one graduation on the index will make a difference of 1-1000 inch in the diameter of cylindrical work which is being turned or ground.

The tool-slide is made flat on top to take various attachments, and has two T-grooves for the tool-post. Ordinary lathe tools are used. The slides are carefully scraped together and the whole slide-rest is neatly ornamented.

For holes and for light outside grinding there is an inside grinder that is arranged so that the lap can be swung away from the hole, for testing the size, and then returned instantly to its original position.

The outside grinder for general work is clamped directly upon the tool-slide and has a vertical screw adjustment. It is arranged so that an emery wheel can be used on either end, and there is a taper hole in the front of the spindle to take arbors for small laps.

Two methods of thread cutting are provided for. The first is on the Fox lathe principle and is attached to the T-groove on the back of the bed. Any even multiple of the lead screw thread up to ten times can be cut, and with a few extra lead screws all ordinary threads can be cut. This method of thread cutting is the most rapid, but under conditions in which a great variety of threads must be cut some machinists will prefer to use the slide-rest. By

this style of thread-cutting attachments this lathe will cut all threads from 5 to 100 per inch, and all between 5 and 50 to the centimeter can be cut.

There is also a special milling attachment, which is a stand consisting of a base made to take the regular head-stock, and is provided with a slide which takes the regular slide-rest. The vertical slide has both a screw and lever feed, so arranged that the change from one to the other can be made instantly. A vise for plain milling, or an indexing head for gear cutting and cutter making, can be attached to the tool-slide of the slide-rest. This combination makes a practical bench milling machine upon which a great variety of work can be done.

While the descriptions of engine lathes are confined to the lathe proper, leaving the subject of their attachments and accessories to be treated in another chapter, it seems advisable to include in the above description the various attachments of this bench lathe, as they are essentially different from those used upon or in connection with an engine lathe, and for different purposes.

In addition to the attachments above described it is frequently the case that others for special work are frequently devised and added to the bench lathe equipment, making it a very useful machine and capable of performing a great many different operations, among them many which cannot be performed on the regular engine lathe without the aid of expensive attachments and fixtures. These qualities make it one of the most useful machines in the shop, especially where small experimental work and fine tool making, jigs, and fixtures are to be produced.

A plain 10-inch swing wood-turning lathe for light manufacturing work or for pattern work is shown in Fig. 284, which possesses some peculiar features worthy of attention. The lathe is built by the F. E. Reed Company.

One of the special features of this lathe is the manner of constructing the head-stock, a vertical section of which is given in Fig. 285. The spindle has a single bearing in the head-stock, which extends over a large proportion of its length, the face-plate being attached to the front end as usual, and the three-step cone pulley attached at the opposite end, fitting upon the spindle for a distance about equal to one of its steps and carried by a flanged collar which

is fastened to it by screws and resting against a fiber washer with the wear or end thrust taken up by a suitable adjustable collar at the end of the spindle.

There is a $\frac{9}{16}$-inch hole through the spindle, whose bearing in the head is $1\frac{3}{16}$ inches diameter and $7\frac{1}{8}$ inches long, while there is also an outer bearing, formed by the small end of the cone running on the outside of the head-stock, $2\frac{1}{16}$ inches diameter and $3\frac{5}{8}$ inches long, giving 50 square inches of wearing surface in the head-stock, which is at least three times more than is obtained in the head-stock of an ordinary wood-turning lathe of this swing.

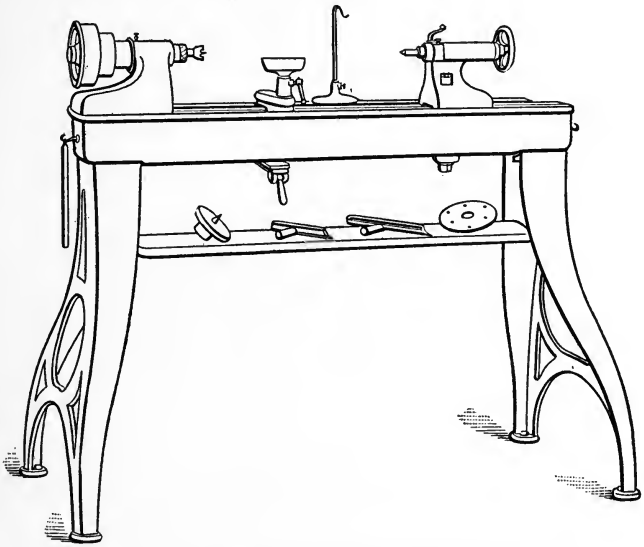


FIG. 284. — 10-inch Swing Wood Turning Lathe, built by the F. E. Reed Company.

The head spindle is a crucible steel forging, and runs in compressed genuine babbitt metal bearings, special care being used to make the inner and the outer bearings truly cylindrical and concentric with each other.

As to the wearing qualities of these head-stocks the manufacturers say:

"We have made and sold over six hundred of these lathes during the last eight years. For over six years we have had one of them in constant use in our works as a polishing lathe. This

is very severe usage for a lathe, but during all this time it has required absolutely no repairs, and no special attention beyond seeing that it was kept properly oiled with a good quality of lubricating oil. We have a large number of most excellent testimonials from schools that have used these wood lathes for a number of years."

The countershaft is of very simple construction and of similar design to the head-stock. In place of the usual tight and loose pulley with the belt operated by a shipper rod and lever, the belt

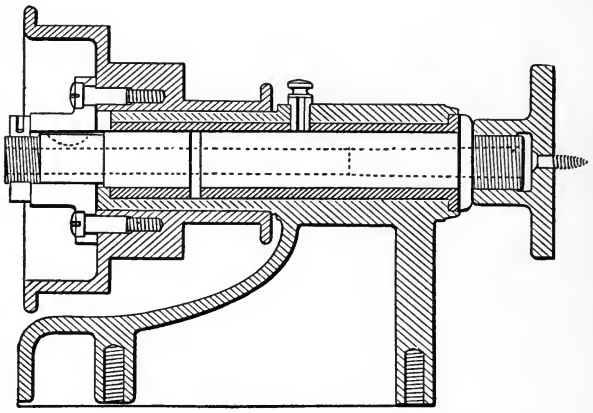


FIG. 285. — Head-Stock of Reed Wood Turning Lathe.

fork is handled by a vertical rod, the lower end of which hangs in a position convenient to the operator, who has only to give it a turn to the right or left by means of a short handle to start and stop the lathe.

The V's in the bed are inverted, or planed out, and the head and tail stocks are fitted into them, instead of upon them, which is the usual way. This allows a perfectly free and level surface across the top of bed and shelf on back side, without any obstruction, besides protecting the V's from being jammed. The upper angle of V is rounded where it meets the surface of the bed, which also prevents jamming or injury of the bed or V at this place.

The T-rests, instead of being the usual form, are concaved, with a projecting lip on the bottom which serves as a finger gage for the operator while using the turning tool. The T-rest holder is

secured to the bed by a clamping device that is neat, strong, and quickly operated. There is a shelf on the back side of the lathe, parallel with the top of the bed, and of the same height; another shelf is also furnished underneath the bed, as shown in the engraving. A hook or holder, with proper support for the same is shown. This is for holding a blue print, or sample of the work, before the operator, and can be raised or lowered. The form of the lathe bed in connection with the extra speed of the legs, and the manner of attaching the lower shelf, all combine to insure steadiness of the lathe when run at the high speed for which it is designed; and each lathe is run five hours at 2,600 revolutions per minute before leaving the works, to see that it is in every respect right.

The workmanship on this lathe is fully up to the standard of the work usually done by this company, which is sufficient guarrantee of its quality.

CHAPTER XX

REGULAR TURRET LATHES

Importance of the turret lathe. Its sphere of usefulness. Classification of turret lathes. Special turret lathes. The monitor lathes. The Jones & Lamson flat turret lathe. Its general design and construction. Its special features. Its tools. The Warner & Swasey 24-inch swing universal turret lathe. General description. Its capacity. Taper turning attachment. Its speeds. The Bullard Machine Tool Company's 26-inch swing complete turret lathe. Its massive form and its general design and construction. Lubrication of tools. The countershaft. The Pratt & Whitney 3 by 36 turret lathe. Its special features. Its general desing. Its capacity. Special chuck construction and operation. The Gisholt turret lathe. Its massive design and construction. Its large capacity. Its general and special features. The Pond rigid turret lathe. Its heavy and symmetrical design. Detailed description. Its operation. General dimensions.

WHILE the regular engine lathe is in almost universal use wherever machine work is done, and while it is the one indispensable tool in every machine shop, the modifications of it in the various forms of a turret lathe are becoming second only in the importance and the range of its work. So great has been the advance in this respect during recent years that nearly all machine shops, even small jobbing shops, are not considered as possessing a passably modern equipment without one or more turret lathes.

Formerly it was not thought worth while to "set up" a job on a turret lathe unless there were fifty or more pieces of the same kind to be machined. It is now a common occurrence to use the turret lathe when only half a dozen pieces of a kind are to be made. The reasons for this are that formerly special tools had to be made for many of the jobs attempted, whereas now we have a great many regular tools furnished with the turret lathe that are of such form and construction as to be available for nearly all the ordinary turret

lathe jobs, while the addition of an extra tool now and then for special work, or a special form, will adopt the turret lathe for a very large variety of work, which may thus be performed with a great degree of accuracy, with a very good finish and in a very economical manner.

Where large numbers of pieces of the same kind are to be made, it is usually the practice to make special tools whenever better work or a larger output can be thereby secured. This will be largely a matter of practical judgment of the man in charge of the work.

We may divide the turret lathe proper, and the engine lathes when used as turret lathes by the addition of a turret, into five classes, according to their design and methods of operation, namely:

First, the engine lathe serving as a turret lathe by mounting a hand-revolved turret upon its *carriage,* in place of the usual compound rest.

Second, the engine lathe serving as a turret lathe by mounting a hand-revolved turret upon the *bed* by means of a shoe or saddle which supports the turret slide.

Third, a turret lathe proper, built as such, with a turret pivoted to a *slide* supported by a shoe or saddle; the turret being revolved and fed by hand.

Fourth, a turret lathe similar to the last and sometimes called a "semi-automatic turret lathe," in which there is a power feed on the cut and the turret is revolved automatically at the end of the stroke.

Fifth, a complete automatic turret lathe with power feed on the cut, a quick power return, and the turret automatically revolved at the end of the stroke.

Those in the third, fourth, and fifth classes are usually provided with a cut-off slide carrying one tool in front and frequently an inverted tool at the back.

Various examples of these different classes will be illustrated and described in the following pages, giving the designs built by several of the prominent manufacturers of this type of machines.

There are, of course, special machines of this general type of lathes built for special purposes. There are modifications of the general class, into the details of which it is impossible to go in these

pages, since it is the object to present distinct types or classes, rather than to expand this work to the dimensions of a cyclopedia on the subject of lathes.

There is one type that deserves special attention on account of its valuable service on small work, and that has been known in the shop for many years as a "monitor" lathe, from the fact, no doubt, of its resemblance to the turret of a monitor. The slide upon which the turret is pivoted is run forward and back by a lever which makes it very rapid in operation. It is usually built for small work only.

The Jones & Lamson flat turret lathe is now so well known that an extended description of it seems hardly necessary, and yet its importance in the manufacturing world of to-day, and its many points of real mechanical interest and importance, demand more than a passing notice.

A front view of one of these machines is given in Fig. 286, this particular machine being 3 x 36-inch size, that is, it will work up a 3-inch bar and the turret has a run of 36 inches on the bed.

As will be seen the bed is supported by strong and well designed legs in a pan nearly the full size of the machine. The head-stock and its gearing is covered by a protecting case which moves with it. One of the peculiar features of the machine being the sliding head which has a transverse movement for the purpose of increasing its effective working capacity. The turret is mounted upon a saddle fitted to broad V's upon which it has a long bearing, insuring accurate results.

The turret is a flat circular plate and is mounted on a low carriage containing controlling mechanism. The connections of the turret to the carriage, and the carriage to the lathe bed, are the most direct and rigid, affording absolute control of the cutting-tools. The turret is accurately surfaced to its seat on the carriage by scraping, and securely held down on that seat by an annular gib. In the same manner the carriage is fitted to the V's of the bed; the gibs passing under the outside edge of the bed. The breadth of this bridge across from V to V makes an unyielding mass to which the tools can be affixed.

The indexing mechanism of the turret is of the greatest importance, and in this particular point the flat turret lathe seems to have an exceptional advantage. Its index pin is located directly

under the working tool, and so close to it that there can be no lost motion between the tool and the locking pin. The turret is turned automatically to each position the instant the tool clears the work on its backward travel, and it is so arranged that by raising and

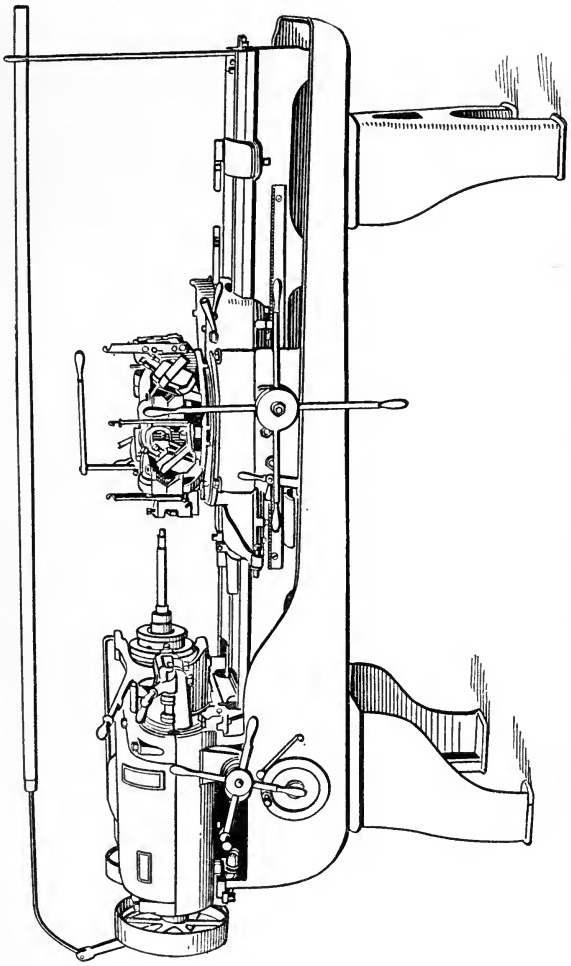


Fig. 286. — 3×36-inch Flat Turret Lathe, built by Jones & Lamson.

lowering trip screws near the center of the turret it may be turned to three, four, or five of the six places without making any other stops.

The power feed for the carriage is actuated by a worm-shaft.

The worm is held into its wheel by a latch which is disengaged by the feed stops. There are six feed stops, one for each position of the turret, and they are independently adjustable. This feature of an independent stop for each tool will be appreciated by the users of the other turret lathes, some of which have only one stop for all turret tools. These feed stops are notched flat bars placed side by side in the top of the bed. They also serve as a positive stop.

The head-stock is of such great importance that weakness here would mean a weak link in the chain. Greatest care has been exercised to make the head-stock equal in stiffness to the turret.

The spindle is ground to size, and its phosphor-bronze bearings are scraped to give a perfect contact. A $2\frac{1}{8}$-inch hole extends from end to end, through which the bars of stock pass.

The caps to the spindle bearings are fitted over large hollow posts which make the top half of the box practically as rigid as the lower half.

The cone and large gear are loose on the spindle and connected at will by friction clutches. The large gear is covered with a hood which protects it from chips and dirt, ensuring smooth running. The back gear is placed below the cone in the head, and a triple back gear, when required, is placed beneath the regular back gear. The regular back gear gives a 4 to 1 proportion, and the triple gear makes a 16 to 1 speed. The triple gear is required for all standard screw threads above $1\frac{3}{8}$ inches in diameter, and in chucking work of large diameter.

The die carriage carries a die of any kind, and a pointer for shaping the end of a shaft or bolt. This carriage is mounted on a sliding bar and arranged to swing into working position. It is provided with lugs which take bearing on the top of the cross-slide, which tool must be in operative position when the die carriage is used. The pointing tool may be used as a turner for reducing the stock.

The bed rests on a "three-point" bearing, making it impossible to twist or vary the deflection of the bed by an unsteady or unnatural foundation.

A drainage bed and double overflow reservoir with circular pump are clearly shown in the engraving, and are too simple to need explanation.

The head receives its power through a triple friction countershaft of unusual proportions and running speed. The three friction pulleys are 12 inches in diameter by 4 inches face; two run 300 revolutions per minute, and the remaining, or middle, pulley runs 150 revolutions per minute.

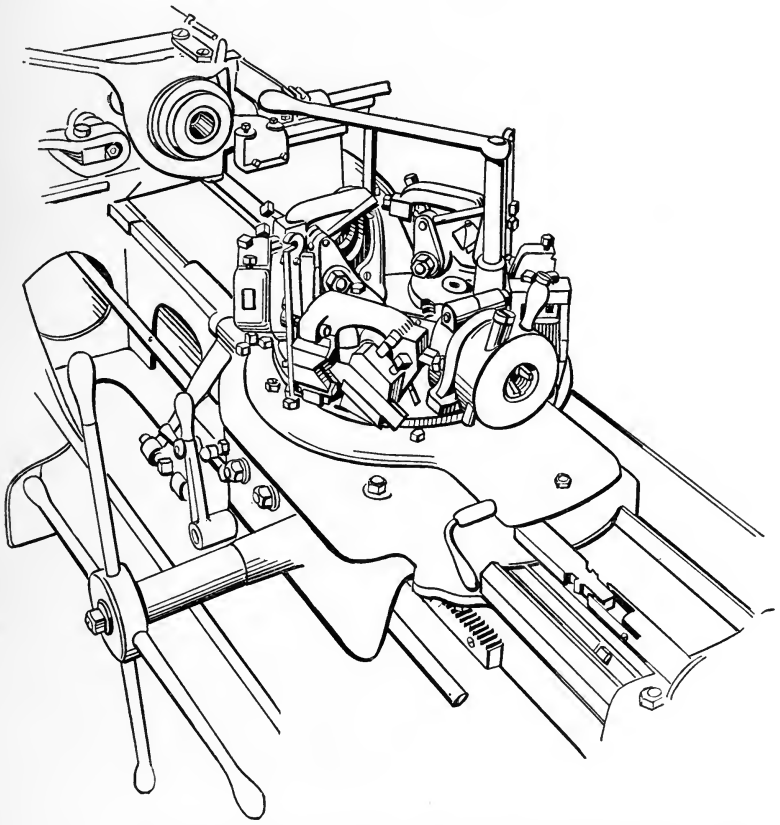


Fig. 287. — Top View of Turret Parts of Jones & Lamson Flat Turret Lathe.

These pulleys have extra long hubs that extend an equal distance each side of the "pull of the belt" (each side of the rim), and perfectly distribute that strain over its entire bearing on the shaft. The shipper rod is so connected that it will act on any one of the three clutches at the will of the operator.

The tools used in this machine are of the usual nature but of improved design in many cases, and are well shown in Fig. 287, as

they appear on the machine, in the top view taken from the rear end, and at the front of the machine, looking toward the head-stock.

The machine tools built by Warner & Swasey are known wherever American machines are used as being of good design, good materials, and good workmanship. In fact, some of the finest machine work turned out in this country comes from their shop.

Their turret lathes are no exception to this rule, and in Fig. 288 is shown their 24-inch swing universal turret lathe, which is a good example of a lathe of this type, adapted to a large variety of work such as iron and brass valves, from 3 to 6 inches, gears, pulleys, bearings, machine parts of circular contour, and general chucking work requiring drilling, reaming, and facing.

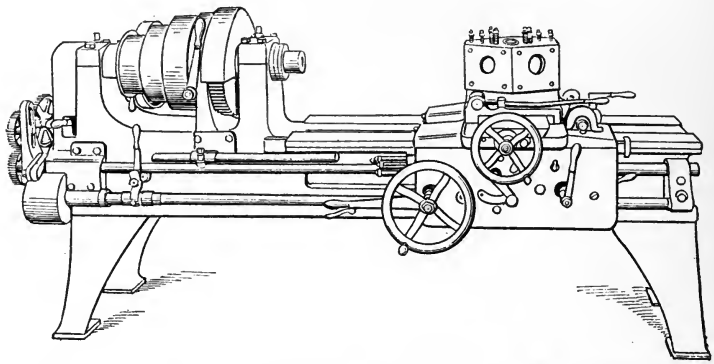


FIG. 288. — 24-inch Universal Turret Lathe, built by Warner & Swasey.

The bed is 8 feet 7 inches long, and is deep and heavily ribbed as it should be in a lathe of this kind. The head-stock is cast in one piece with the bed, rendering it strong and rigid against the weight of the work and the torsional strain of the machining operations. The spindle cone is of three steps, the largest of which is 16 inches in diameter and adapted for a 4-inch belt. The spindle has a $2\frac{1}{4}$-inch hole all the way through. From the end of the spindle nose to the face of the turret is 36 inches when at its extreme position.

The friction back gears give two speeds without stopping the machine, the ratio being 8 to 1.

The turret is hexagonal in form and has a very large bearing upon the carriage. It is 14 inches across flats and has six 3-inch

holes, allowing 2½-inch bars to pass through it. The carriage has a longitudinal travel of 32 inches and a cross travel of 12 inches.

Two sets of independent adjustable stops are provided for each face of the turret, one operating with the longitudinal and the other with the cross travel of the carriage. When the general work which the lathe is expected to do renders these stops superfluous, they may be omitted from the regular equipment.

The geared feeds, both for the longitudinal and the cross cuts, give six changes, any one of which is made instantly available by moving a lever. These feeds are so designed that they will give respectively 4, 7, 12, 16, 28, and 48 to the inch for every revolution of the main spindle; that is, the spindle will make these various number of revolutions while the feeds advance 1 inch.

The lead screw is provided with the proper gears for cutting 2, 3, 4, 5, 6, 7, 8, 9, 10, 11½, 12, and 14 threads per inch. Finer threads than these are not likely to be required on a lathe of the capacity of this one.

There is a taper turning attachment for turning tapers up to 3 inches per foot, which is furnished only when specially required.

The machine is driven from a triple friction countershaft which has 16-inch pulleys adapted for a 4½-inch belt. One of these pulleys runs at a speed of 100 revolutions per minute and the other at 140, which gives twelve spindle speeds ranging from 53 to 264 per minute without the back gears, and from 7 to 30 revolutions per minute when the back gears are in use. A third pulley is designed to run the spindle backwards.

The weight of this machine is 4,500 pounds, which shows its substantial and massive character.

This firm make a variety of styles and sizes of turret lathes adapted to a large class of products.

The Bullard Machine Tool Company enjoy a reputation for turning out first-class machines. This applies equally to the design, the material, and the workmanship.

In Fig. 289 is shown one of their 26-inch swing complete turret lathes, or as might be more comprehensively termed, turret machines

The machine is of massive design, the bed deep and strongly braced. It is provided with heavy top members or tracks, carrying broad V's, and surrounded by a proper pan for catching and carry-

ing off whatever lubricating material is used. The bed is well supported at the head end by a broad cabinet, made long enough to furnish a solid support under the front box of the main spindle. At the rear end, where much less support is required, a leg is deemed sufficient.

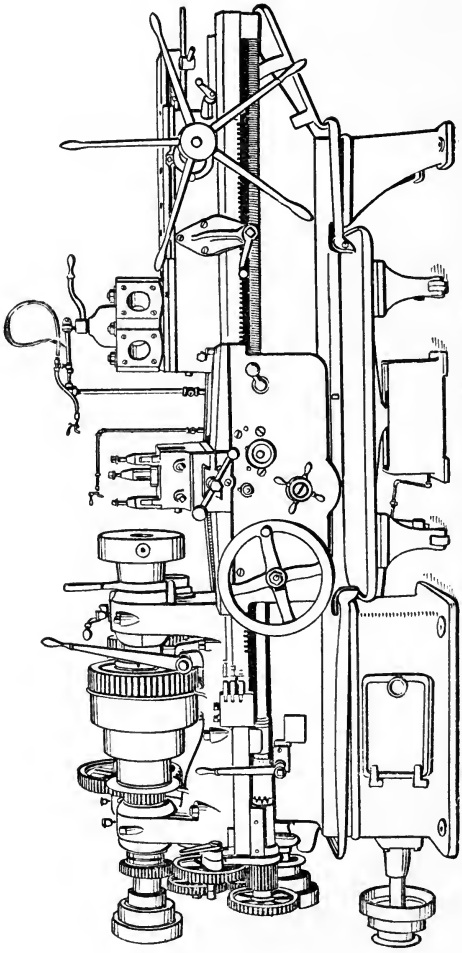


Fig. 289. — 26-inch Turret Lathe, built by the Bullard Machine Tool Company.

The head-stock is of ample length to furnish large housings for the main spindle boxes, as well as sufficient space for a three-step cone of liberal dimensions and the necessary back gears, clutches, etc. The largest section of the cone is 16 inches in diameter and

adapted for a $4\frac{1}{2}$-inch belt. The spindle is bored out to $3\frac{3}{8}$ inches and is fitted with a chuck of suitable design for taking hexagonal, square, or round bars. The spindle is driven by triple gearing and is fitted with a patented friction clutch for instantly changing from belt speeds to either set of gears without stopping. The change to back gears is made by moving the clutch lever, and to the triple gears by means of the lever shown on the back of the front spindle bearing, thus obtaining three speeds from the cone, three through the double train of gears, and three through the triple train of gears, making nine spindle speeds in all.

The carriage is designed to be heavy and strong and has a long bearing upon the bed, to which it is securely gibbed. It is provided with a taper attachment, reversible cross and lateral feeds, which are driven by gearing from a splined lead screw, the thread of which is used only for thread cutting, thus insuring accurate work of this kind. At the front of the bed and directly below the large step of the spindle cone are seen the carriage stops, which are adjustable in a group upon the bed, and independently as the work may require.

The cross-slide is unusually wide and is operated by a screw and a three-ball crank. There are three tool-posts so that forming cuts may be made as well as the usual cutting-off operation performed.

The turret is hexagonal in form and 14 inches across the flat surfaces. The tool holes are $3\frac{1}{2}$ inches diameter and the center stud is drilled with a hole of the same diameter so as to allow a bar to pass entirely through. The tool faces are also drilled with four holes each for use in bolting on large tool-holders. The turret is provided with an automatic feed and trip, and with a patented device for unlocking and revolving it at any point between 8 and 22 inches of its run. It is pivoted upon a long top slide provided with stops at the rear end and may be operated by the automatic feed or by the capstan levers in the usual manner. The top slide is well supported by a long and broad bottom slide or base, firmly clamped at any point on the bed, and moved along the bed by a rack and pinion device.

The lubrication of tools is amply provided for, the lubricant being pumped from a tank on the floor and up through two pipes properly jointed so as to deliver two streams of lubricating compound at a

time at the points desired. Situated over this tank and beneath the pan surrounding the bed, is a secondary pan supported on wheels so as to be readily removable when it is desired to clean it out. Into each end of this, oil and chips drip from the two lips seen at the right and left. This feature will be duly appreciated by the operator, who has been accustomed to clean out the pans of the older style machines.

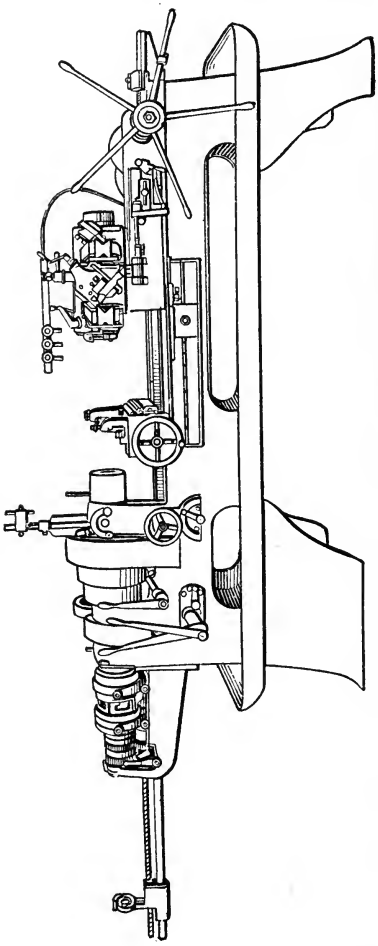


Fig. 290. — 3×36-inch Turret Lathe, built by the Pratt & Whitney Company.

The countershaft has three friction pulleys 20 inches in diameter, for 4½-inch belt, and runs respectively 96 and 144 revolutions per minute forward and 144 revolutions backward. The weight of the entire machine is 9,500 pounds, which is a very liberal weight for a machine of this capacity, and insures great rigidity and strength of its principal parts.

Another notable machine brought out by the Pratt & Whitney is their 3 x 36 turret lathe; that is, a lathe capable of handling a 3-inch bar of round stock and in which the turret has a run of 36 inches. The machine is well shown in perspective in Fig. 290 and a plan of it is given in Fig. 291.

As may be assumed from its capacity it is a very rigid machine in which the bed, head-stock and pan are cast in one piece. On account of the great quantity of oil that is necessary to use upon it when machining bar stock, the bed is set in a pan of ample proportions and well supported on heavy legs, those under the head-stock

being very broad and furnishing a support under the entire length of the head-stock. The compound casting for bed, head-stock, and pan is shown in Fig. 291.

One of the new features of the machine is the chuck, which is arranged to handle bar stock considerably above or below size with the same gripping force as if the bar were true to size. This is a feature of much value in machining the larger sizes of rough stock in which there is usually considerable variation in the diameter even at different points along the same bar, as well as the frequent occurrance of slight bends in the bar that render it difficult to handle in the ordinary turret lathe chuck.

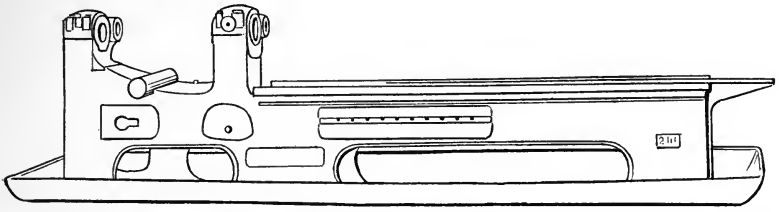


Fig. 291. — The Single Casting Combining the Bed, Head-Stock and Pan of the Pratt & Whitney Turret Lathe.

This machine is regularly driven by a three-step cone pulley adapted for broad, double belts. This cone pulley, in conjunction with the double friction back gears and a three-speed countershaft of improved design, gives to the main spindle twenty-seven speeds, or nine for each step of the cone. These nine different speeds with an open belt range from 78 to 550 revolutions per minute, and the eighteen back gear speeds run from $9\frac{3}{10}$ to 182 revolutions per minute. This great range of speed adapts the machine to handling all work, not only from 3 inches in diameter down, but all classes of materials as well, so that it does its work under a very large range of conditions and circumstances.

The turret slide has power feed for turning lengths up to 36 inches, and the driving device for the feed mechanism for the turret and cross-slides is by means of a silent chain which is driven from a sprocket wheel on the spindle, from whence it leads down to a gear box containing the variable speed gears for giving the different rates of feed. The shaft for operating the turret and cross-slide

located at the rear of the bed, and the gear box mechanism is operated by the two short levers in front of the head-stock as seen in Fig. 290, and by which four rates of feed in either direction are obtained for either the turret slide or the cross-slide. The turret feeds range from .007 to 0.23 inches and those of the cross-slide from .0014 to .004 inches per revolution of the main spindle.

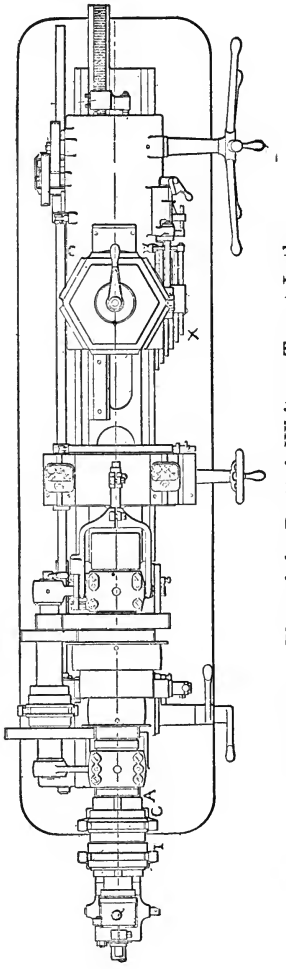


Fig. 292. — Plan of the Pratt & Whitney Turret Lathe.

There are dovetailed upper and lower edges on the hexagonal turret faces, to which tools may be rigidly clamped, and each tool is provided with an independent stop which is carried in an adjustable bracket fixed to the front of the bed.

By referring to the plan view of the machine in Fig. 292, at X, it will be seen that there are six stops placed side by side in the bracket above referred to. Each one of these, when adjusted, is held by an independent screw. As the turret is rotated a cam at the bottom operates an arm carried on a rock-shaft at the side of the turret slide and swings it into line with the proper stop in the bracket. This rocker arm, or turret stop, is always rigidly supported, as in all positions the rear face rests against a machined surface on the slide.

The cross-slide carries two tool-posts of good design for holding tools rigidly, and may be adjusted at any point along the bed that the work requires by a hand wheel at the front end of the head-stock

The peculiar construction of the chuck referred to above is worthy of special attention and may be understood by reference to the sectional engravings and the following description of its mechan-

ism. In Fig. 293 is shown a section of the chuck and its related parts, and in Fig. 294 its operative mechanism. In the former engraving D is a portion of the nose of the spindle, and E the cap screwing on over it. G is the chuck jaws and H the closing collar. This collar as well as the jaws of the chuck and the wearing surfaces of the cap are hardened and ground, and the rear end of the latter is made a sliding fit in the spindle bore, while its front end is ground to a sliding fit in the ring F, which is hardened and forced into the nose of the spindle D, and then ground while the spindle is running in its own journal boxes.

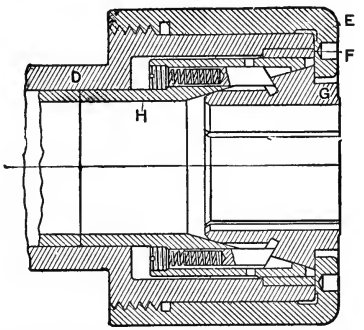


FIG. 293.—Chuck Construction of the Pratt & Whitney Turret Lathe.

The chuck jaws have square shoulders abutting against the cap and open and close without end movement, as the spring plugs

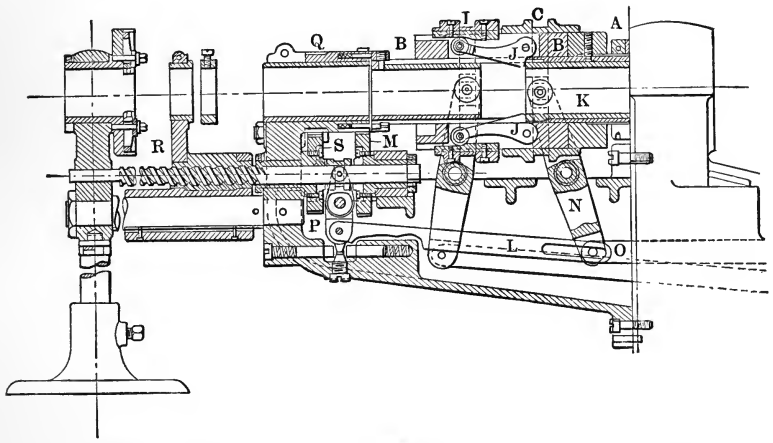


FIG. 294. — Chuck and Rod Feed Mechanism of the Pratt & Whitney Turret Lathe.

keep them in contact with the cap when released by the closer. The jaws for each nominal size of stock are adapted to hold bars $\frac{3}{32}$ inch over size, or $\frac{1}{32}$ inch under size, and anywhere within this range they maintain a parallel grip on the bar. This is due to

the fact that the contact between jaws and closer is always a line contact along the middle of each jaw, the surface at either side of this line being relieved so as always to clear the conical seat in the closer.

To give the jaws a uniform gripping pressure upon the work, regardless of the variation in size from standard, provision is made for first bringing them into contact with the bar by operating a lever, after which they are closed tight by means of a second lever, both levers being mounted at the front of the head and about a common axis, as shown in Fig. 290.

Referring again to Figs. 292 and 294 it will be seen that the rear end of the spindle carries two sliding rings actuated by independent yoked levers; these latter are connected by links with the operating levers just mentioned.

The ring C, Fig. 293, is fitted with a pair of racks each of which engages with a spiral pinion formed at the center of a right and left-hand screw; the front ends of the screws fit holes tapped in collar A, which is secured to the spindle, while the rear ends are screwed into the sleeve B which carries the chuck-closing fingers J, whose heels are always in contact with the lugs of the chuck-closing tube K, the rollers at the outer ends resting against the shoes carried in the ring I. The yoked lever N, operated through the link O by the inner of the two vertical levers in front of the head, is connected also by the slotted link L with the stock-feed mechanism at the rear.

When the chuck is opened and the stock stop swung down from the head, the inner lever is thrown over, forcing the link L toward the rear and clutching the gear M to the feed screw, which is then driven from the spindle in the right direction to draw the bar forward against the stock. When the bar is in contact with the stop the clutch throws to the middle position as shown, stopping the screw; the lever is then thrown in the opposite direction, sliding the ring C on its bearing, and by means of the racks, spiral gears and right and left-hand screws the sleeve B, with fingers J and tube K, is drawn forward, forcing the chuck jaws into contact with the bar. The outer lever is then operated to push back the ring I and close the chuck down hard upon the work.

The manipulation of the levers takes but an instant, and it will

be noticed that no matter what the position of the closing tube K may be when the jaws are in contact with the stock, the pressure exerted through the fingers J and the sliding ring I is always uniform and effective.

The upright at the outer end of the stock-feeding apparatus carries an adjustable rotating support for the bar stock, and the traversing bracket R actuated by the screw is adapted to receive various sizes of bushings corresponding to the collars secured to the stock.

When the feed bracket has reached its extreme forward position it is run back by moving to the left the short lever shown in Fig. 290, which clutches the reversing gear M to the screw. The clutch between gears M and S is normally held in mid or inoperative position by the spring plungers at the lower end of the arm P. The gears are driven continuously (so long as the spindle is running ahead), by the double gear Q on the sleeve above; the clutch connecting the driving gear to the spindle end is so formed, however, as to be inoperative if the spindle is reversed, thus making it impossible to engage the feed accidentally before the spindle is again started ahead.

Taken altogether this mechanism represents the latest and best development in its line for the purposes intended, and is in keeping with the usual practice of this company of careful designing and good, practical construction.

The Gisholt turret lathe occupies a somewhat different field than that usually covered by the other manufacturers of turret machinery, in that the machines are much larger and heavier and of much greater capacity, handling very large and heavy work. While there are none of the other builders who make a turret lathe of much over 30-inch swing, the Gisholt lathe is built as large as $41\frac{1}{2}$ inches, this largest size weighing about eight tons, while there are very few of those of other builders weighing more than one half as much.

Figure 295 shows this machine swinging $41\frac{1}{2}$ inches over the bed. As will be seen, all the parts are very massive and calculated to withstand the heaviest strains to which a machine of this type could possibly be subjected.

The bed reaches to the floor (or properly to a well built foundation raised slightly above the floor, upon which a machine of such

weight should always be placed), and has the head-stock cast in one piece with it so that the greatest amount of rigidity may be preserved. The housings carrying the boxes for the main spindle are heavy and of ample width and are three in number, giving all necessary support to the spindle. The back gears are placed over the spindle and out of the way, making the machine considerably narrower at this point than if they were placed in the rear, as is usually the case. They are of coarse pitch and wide face, giving ample power for all occasions.

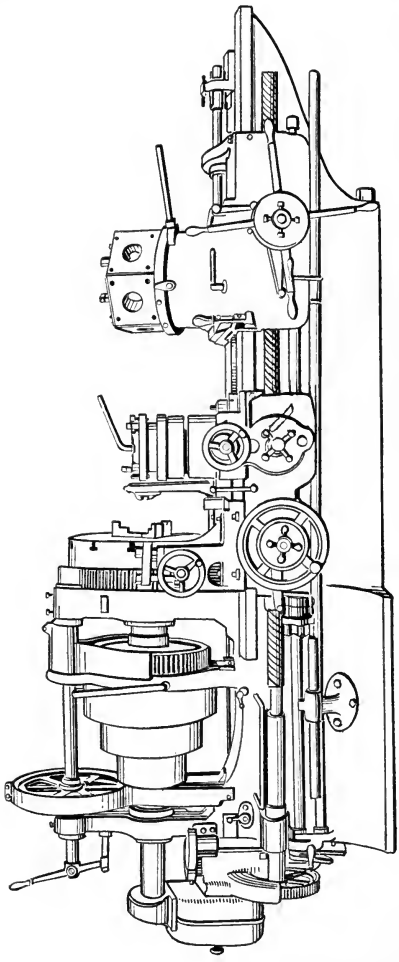


Fig. 295. — 41½-inch Turret Lathe built by the Gisholt Machine Company.

The wearing surfaces throughout are made very large, all sliding surfaces being scraped to standard surface plates, and all spindles, arbors, etc., are finished by grinding on dead centers. The head-stock is friction back geared, and is also provided with an extra powerful back gear for doing the heaviest class of work for which the machine is adapted. The spindle is made of forged steel and runs in reamed and scraped bronze boxes.

The turret is hexagonal and very large, in order that heavy tools may be rigidly secured to it. It slides directly on the ways of the machine and hence has the full traverse of the bed. This permits of the use of long boring bars, the outer ends of which may be supported in a bushing in the chuck.

The carriage is provided with a turret tool-post carrying four tools, any one of which may be instantly brought into position for cutting. These tools are independently adjustable as to height. The cross feed has micrometer index reading 1-1000 of an inch. Power cross feed and taper attachments are provided if desired. For each tool in the tool-post and for each face of the turret feed and dead stops, independently adjustable, are provided, by means of which the feed may be thrown out automatically at any desired point. The feed works are entirely novel and permit of four changes of feed being instantly obtained, either from the end of the machine or from the turret slide. The feed is also instantly reversible.

The four tools which may be carried in the carriage tool-holder are held by means of a large square plate, forced down by a heavy screw in its center. The tools are placed under the edges and parallel to them and brought into active position by the entire tool-holder top, swiveling turret-like upon a central pivot, when raised to the proper position for that purpose. Stops, independently adjustable, are arranged for each of these tools, both for lateral and cross feeds.

Turret stops are arranged at the rear of the machine and may be severally brought into working position by rotating the cylindrical carrier. They are, of course, independently adjustable.

In Fig. 296 is given a view of the top of the machine, which will serve to show the various operative parts of the turret and its stops, the revolving tool-holder on the carriage, and the taper attachment, much more clearly than is shown in the front view in Fig. 295, and on a much larger scale.

This description might be much more elaborate but the machine is quite well known among practical shop men and those having any special connection with this branch of machine business, and further details do not seem necessary.

Pond tools are considered good tools and are usually designed heavy enough and strong enough to stand the strain of any work that the machine may be called upon to do. While this remark applies to a great extent to all Pond tools, it is particularly applicable to the Pond rigid turret lathe, represented in Fig. 297, which well illustrates its massive construction. This is particularly true of the tool carriage and of the saddle which supports the turret, as

well as the bed, which has the supporting legs cast with it. Its design is such as to furnish the best resistance and support for both the strain of weight and of torsion.

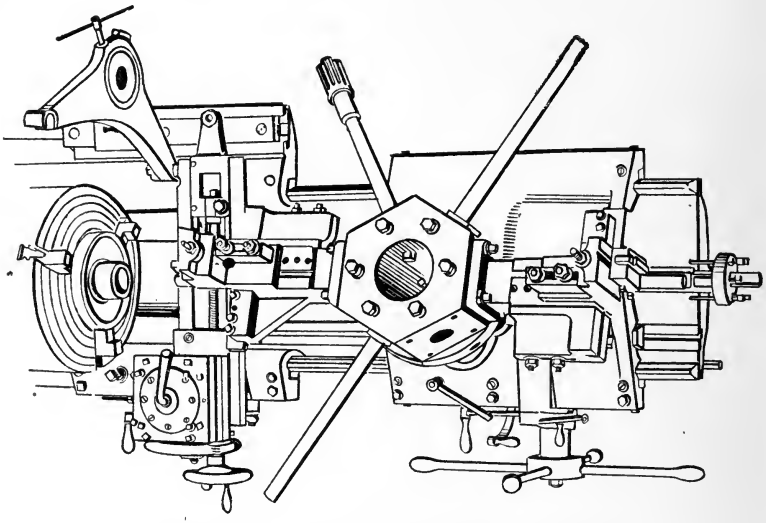


FIG. 296. — Top View of Gisholt Turret Lathe.

The swing over the carriage is almost as great as that over the ways, which permits the use of tool-post tools directly behind the

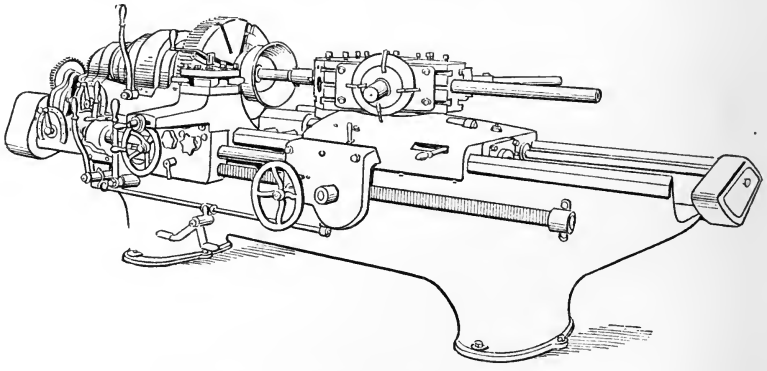


FIG. 297. — The Pond Rigid Turret Lathe.

work, and also allows the carriage to be run behind the chuck so that the turret may be brought up close to the chuck. Short, rigid tools with practically no overhang and short boring bars can

therefore be used. In no other machine is this feature available. The design of the turret provides for six faces, three of which are of extra width, permitting the heaviest facing, multiple-turning, and forming tools to be rigidly attached.

This turret is illustrated in plan in Fig. 298 and in elevation in Fig. 299, showing the narrow faces at A, A, A, in both figures and the wide faces B, B, B. In the use of a tool held upon a shank it is obvious that the width of the face A is ample, as all that is necessary is sufficient strength around the tool-hole D, which is provided for in the square surface at A. In the case of large fixtures such as the inserted blade reamer for a conical hole shown at the front of the turret in Fig. 297, the very wide face, provided with a groove across the center into which a rib on the tool base fits, and the two T-slots for the four bolts securing it to the turret, are manifestly very valuable in holding the tool stiff and rigid, and doubtless suggested the name of "rigid turret," as there is every reason to assume such condition from the excellent design.

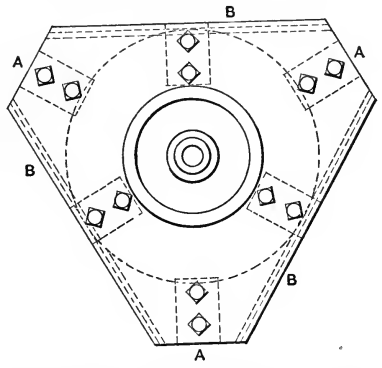


FIG. 298. — Plan of the Turret of the Pond Rigid Turret Lathe.

The turret is semi-automatic in its movements, the rapid forward and return movement and its rotation being controlled by one lever. It is indexed by worm and worm-wheel, centered by taper tool-steel locking pin, and clamped automatically by wide clamp rings having bearing *a* on its entire diameter, thus insuring both accuracy and rigidity. It is arranged with hand wheel for operation by hand if desired.

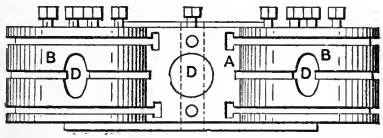


FIG. 299. — Elevation of the Turret of the Pond Rigid Turret Lathe.

Separate feed-screws are provided for turret and carriage, giving instantaneously six different feeds with same change-gears. Any feed available may be used on both the turret and cross carriages at the same time.

The spindle bearings are of very large diameter and the hole in the spindle is $4\frac{1}{4}$ inches in diameter, counterbored to $5\frac{1}{8}$ inches in diameter, 18 inches in depth, so as to permit boring bars with both roughing and finishing cutters to be used; the roughing cutter being inside the spindle when the finishing cutter is at work. Head-stock has self-oiling bronze bearings and a two-step cone, providing for a very wide belt.

A complete line of standard tools is furnished with these machines for boring, facing, and turning. The firm has a department solely for this purpose, making a specialty of designing and furnishing box tools and dies for any work that can be handled on a turret lathe, and adapted to this machine and other machines of its class.

It will be noticed by reference to Fig. 297 that the changes of speed in the head-stock are effected by a single lever; the changes of feed by three levers and two index arms giving a great variety of feeds and adapting the machine to work on all kinds of metals and all diameters and forms having a circular cross section.

The general dimensions and capacities of the machine are as follows: swing over the V's, 28 inches; over the cross-slide, $24\frac{1}{2}$ inches; hole in spindle, $4\frac{1}{4}$ and counterbored to $5\frac{1}{8}$ inches for a depth of 18 inches from the front of the spindle. This machine will take in a bar $4\frac{1}{8}$ inches in diameter. The spindle bearings are: front bearing, 8 x 9 inches; rear bearing, $5\frac{1}{2}$ x 6 inches. All threads from $\frac{1}{2}$ to 64 per inch can be cut. The spindle speeds are twenty in number, and from $1\frac{1}{2}$ to 182 revolutions per minute in regular geometrical progression. The gearing ratios for the head-stock are respectively $3\frac{1}{2}$ to 1, $8\frac{1}{2}$ to 1, 22 to 1, and 57 to 1.

The tool-holding holes in the turret are 3 inches in diameter. The distance from face of chuck to face of turret when at its extreme position is 5 feet 4 inches. The travel of the turret is 5 feet and its speed is 25 feet per minute. The cross travel of the carriage is 36 inches, which is very liberal. The turret tool-post on the carriage has four tool positions.

The length of the machine over all is 15 feet $11\frac{1}{2}$ inches, and its width 5 feet 3 inches. The machine complete weighs 12,500 pounds, a very liberal weight for a machine of the capacity of this one.

CHAPTER XXI

SPECIAL TURRET LATHES

The R. K. Le Blond triple-geared turret lathe. General description. The Springfield Machine Tool Company's 24-inch engine lathe with a turret on the bed. Its special features. Its general dimensions. Its design and capacity. Turret lathe for brass work built by the Dreses Machine Tool Company. Its general description. Special features and construction. A combination turret lathe built by the R. K. Le Blond Machine Tool Company. A useful machine with many good features. A 15-inch swing brass forming lathe built by the Dreses Machine Tool Company. Its distinguishing features. Le Blond Machine Tool Company's plain turret lathe. Plainness and simplicity its strongest points. General dimensions. The Springfield Machine Tool Company's hand turret lathe. A modification of their 18-inch swing engine lathe. The Pratt & Whitney monitor lathe or turret-head chucking lathe. Its general features and construction.

The R. K. Le Blond Machine Tool Company build a line of well designed and substantial turret lathes, a representative of which is shown in Fig. 300, which is of a 31-inch swing, triple-geared machine with double back gears and a friction device, and is driven

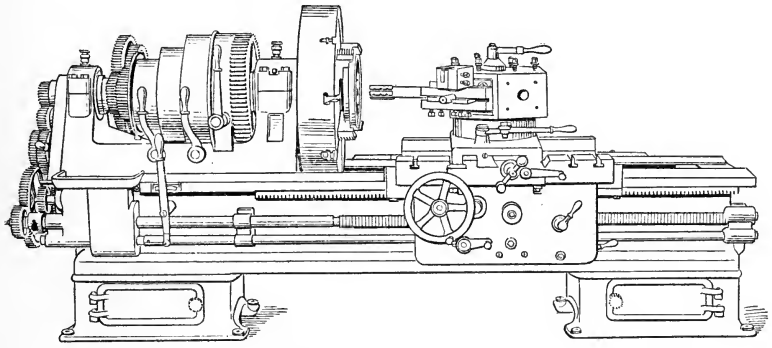


Fig. 300. — 31-inch Triple Geared Turret Lathe, built by the R. K. Le Blond Machine Tool Company.

from a triple-speeded friction countershaft, by means of which fifteen speeds may be had without changing a belt, thus adapting it to a great range of work requiring different speeds in order to do the work with the maximum degree of efficiency.

Special attention has evidently been given to the design, so as to have it very strong and rigid in all parts which support the working members so as to afford an ample protection against vibrations when taking heavy cuts. The head-stock is unusually large and massive.

It is back geared 55 to 1, so that it has enormous power for forming and facing cuts. The turret has a double bearing on the slide, making it perfectly rigid. It is locked with their patented locking pin, having a bearing on both sides of the locking ring. All wear can be taken up between the turret and stem by means of a taper bushing. The carriage is very heavy, gibbed both back and front, and the rack pinion is supported on both sides of the rack.

This lathe is especially fitted for box or forming tools, and will work a nest of roughing tools to good advantage. Changes of feed can be had instantly by the use of the lever shown on the bed; and, with half nuts in the apron, and any tapping work can be done with positive lead from the screw. A specially strong chuck is furnished having, in addition to the hardened jaws, a set of soft ones to be used for the second operation, so as to secure perfectly concentric work, which is frequently difficult, particularly when the limits of measurement and the exact running of the work are important conditions.

It will be noticed that the feed gears are of broad face and well adapted to heavy work and that the lathe carries a very heavy and strong chuck, which is all-important when heavy cuts are to be made as well as when the work itself consists of large and heavy pieces. It is particularly well adapted to machining forging up to the limits of its swing and of rough outline, which usually prove very trying to any lathe containing any inherent weakness of construction.

As an example of the second class, the 24-inch swing engine lathe, built by the Springfield Machine Tool Company, is shown in Fig. 301. In this case it will be seen that the carriage remains on the lathe as usual and may be used in conjunction with the turret

which is pivoted to a slide, supported by a bed or saddle which rests upon the V's and is fixed to the bed in the usual manner.

While turrets thus applied to an engine lathe are usually equipped for hand feed only, there is a device furnished with them by some builders, by the use of which a power feed is provided. This is the case with the lathe here shown.

The turret slide is supplied with variable power feed and automatic stop, which in no manner interferes with the usual engine lathe feeds and screw-cutting mechanism, each being entirely independent of the other, and can be used separately or collectively as the work demands. Therefore, should conditions exist where the same lathe is to be used for turning work between centers as well as when held in chuck or face-plate, the tail-stock can be fur-

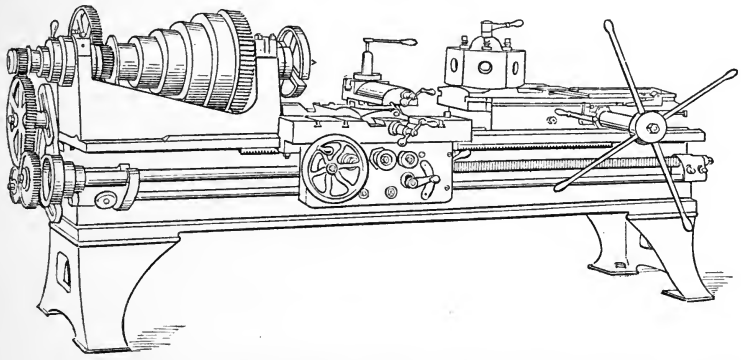


FIG. 301. — 24-inch Swing Engine Lathe with Turret on the Bed, built by the Springfield Machine Tool Company.

nished with which the turret interchanges, and either a regular complete engine lathe is at hand or a modern turret lathe.

The turrets are all furnished with power feed, but are made to revolve automatically or by hand to suit the user.

The details are constructed with great care. The index ring is of large diameter and made of tool steel. The locking plunger is also made of tool steel slides between large bearings, with provision for adjustment to take up wear.

All the parts pertaining to the automatic revolving mechanism of turret are also made of tool steel and hardened.

Feeds are engaged and disengaged by levers conveniently placed in front of the pilot wheel.

Although these turrets are of massive proportions, and possess rigidity to an unusual degree, they are very conveniently handled, an important factor towards the ends sought.

Some of the dimensions of these turrets are as follows: width across flats, 12½ inches; diameter of holes for holding tools, 2½ inches; length of the top slide upon which the turret is pivoted, 46 inches; width of the bearing surface, 11 inches; length of bottom slide, or saddle, 30 inches; width of bottom slide, 11 inches; extreme distance between lathe spindle and turret face on a lathe with a 10-foot bed, 42 inches; weight of turret, 1,200 pounds.

These figures will give a good idea of the substantial design of this device, which was evidently intended for heavy work and hard usage. It is very important that all parts of a turret, of whatever kind of type and for whatever purpose, should be strong, rigid, and well fitted. If not of sufficient weight to give it the necessary strength it will fail when put to the actual test of hard work. If not of sufficient rigidity the tools will "chatter" and either seriously mar or spoil the work. If all the parts are not well fitted the tools will not "line up" with the head-stock spindle, and as a consequence true work cannot be done in the machine. It may be stated as a practical fact that in turrets built by the best manufacturers it is not usual to find the entire six holes lining up perfectly with the head-stock spindle. While the present machines of this type are far ahead of those built a few years ago, in these respects, the practical shop man will be fairly well satisfied with a turret if he finds but two of the holes "dead true," two more near enough true for the usual class of work, and the remaining two considerably out of true. And this will generally be the case even though the "finish boring" of these holes is done with a tool carried by the head-stock spindle in the lathe that the turret is fitted up for. To the young machinist this may seem strange, but it is nevertheless true, and true of probably a large majority of turret machines of the present day.

A very complete turret lathe for working brass and other similar metals is built by the Dreses Machine Tool Company. It is shown in Fig. 302, and is known as a 15-inch friction back geared brass turret lathe, and is provided with a special chuck, cutting-off slide and a slide-rest.

The bed is of the box pattern with a dovetail top, which provides the best means for keeping alignment and for quick and firm gripping of the turret and cut-off rest. It is supported on the three-point principle to avoid springing and getting out of alignment through careless setting up or settling of floors and foundations. The top is provided with holes for the oil and chips to drop through.

The head-stock on the smaller machines is cast in one piece with the bed. In this machine it is attached to the bed by gibs and bolts. The housings are provided for either phosphor bronze or babbitt metal bearings.

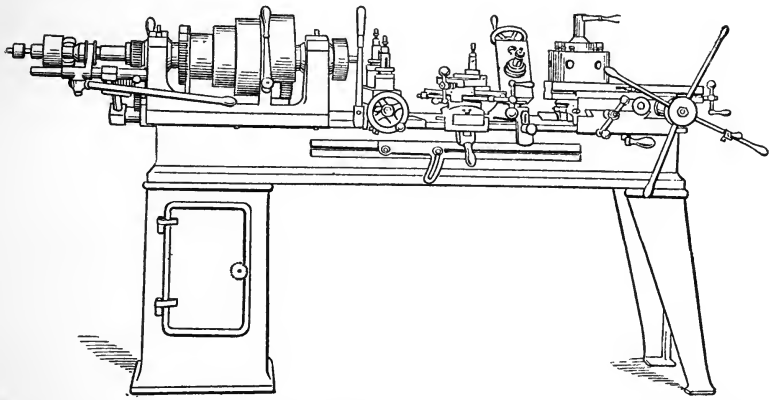


FIG. 302. — 15-inch Friction Back Geared Brass Turret Lathe, with Special Chuck, Cutting-off Slide and Slide-Rest, built by the Dreses Machine Tool Company.

The friction clutch back gear is of a new design, very simple in operation and positive in action. The wear is taken up by a screw driver from the outside, without even removing the cover.

The spindle is of special hammered crucible steel. The bearings are ground and run in phosphor bronze boxes with special means for oiling and taking up the wear.

The turret revolves automatically on a ground steel stem with special device for taking up the wear. It is provided with a set-over device. The top slide can be operated either by the crank and screw shown at the rear end, or by the capstan levers in the usual manner. One of the capstan handles is provided with a short handle at right angles with it for convenience in quick operations.

The entire capstan wheel may be removed and a crank substituted when quick operations are constantly required.

The longitudinal and cross-feed stop screws are located in easily accessible places. The base slide is clamped to the bed by a single handle and the operation of clamping is by a single motion.

The turret locking bolt withdraws by the return stroke of the top slide, so that the operator needs only to revolve the turret. This is equally effective as a full automatic turret, but less costly and complicated.

The index ring and key are of hardened steel and ground. The square locking bolt is provided with an adjustable taper gib, and a coil spring for actuating it.

The cutting-off slide is extra heavy and is provided with an independent stop for both front and rear tools. It has both a screw and crank wheel feed and a lever feed, either of which may be used as occasion may require.

The slide-rest is of much better design and construction than is common in similar work and is a very useful addition to the lathe, increasing its capacity in handling work of complicated nature, as by its use another series of cuts may be made without removing the work from the chuck.

The special chuck is so arranged that the work may be gripped or released while the machine is running, thus avoiding the necessity of stopping to feed the bar in every time a piece of work is cut from the bar.

The feed is a positive geared device that should do the work well and efficiently.

Taken altogether the lathe is well designed and has been provided with many very useful devices that no doubt prove convenient and effective in practical work. The special forming slide located next to the turret may, of course, be located at any point in relation to the usual cutting-off slide or the slide-rest that may be desired in order to properly perform the work in hand. Either of these adjuncts may be removed when not required for the piece to be machined, or all may be used upon a long or complicated job when needed.

A combination turret lathe built by the R. K. Le Blond Machine Tool Company is shown in Fig. 303. The head-stock and its appen-

dages are the same as those shown in Fig. 300, and the bed and cabinets supporting it are the same. The turret and carriage arrangements, however, are quite different and adapted to a much larger range of work.

The carriage is fitted with a turret tool-post which will carry four tools under the massive top plate shown, and which are securely fastened by the set-screws through it, thus materially increasing its capacity for different cuts on the same piece of work. A binding lever on its top secures the tool clamp in any desired position.

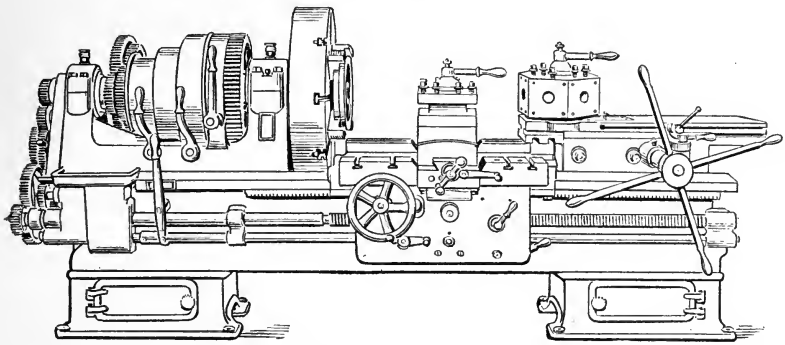


FIG. 303. — Combination Turret Lathe, built by the R. K. Le Blond Machine Tool Company.

The turret is very heavy and well supported by the turret slide, upon which it is pivoted, and a long base slide or saddle. It is run forward and back by a capstan or pilot wheel with long levers giving ample hand power.

The turret can be connected with the carriage so as to be used for thread cutting and for tapping, as it thus connects positively with the lead screw by way of the apron. This feature is valuable in many respects.

In addition to the above convenience it has its own automatic feed, which has an unusually long run. As the turret has six large flat faces, each tapped with four holes in addition to the central hole for holding tools, it is well adapted for carrying large box tools, facing tools, or farming tools for special work.

The turret has the usual stops for regulating the length of the cuts, and a heavy binding nut lever for holding it firmly in any desired position.

It is altogether an exceedingly useful machine, combining many practical features, great weight, strength and rigidity, and consequently capable of performing very heavy work.

The turret-forming lathe is a machine that is very useful on a variety of work in which complicated outlines occur in a piece of circular cross section, and in which a large number of pieces of exactly the same design and contour are required. In handling brass work of this variety, what is known as the forming slide, verti-

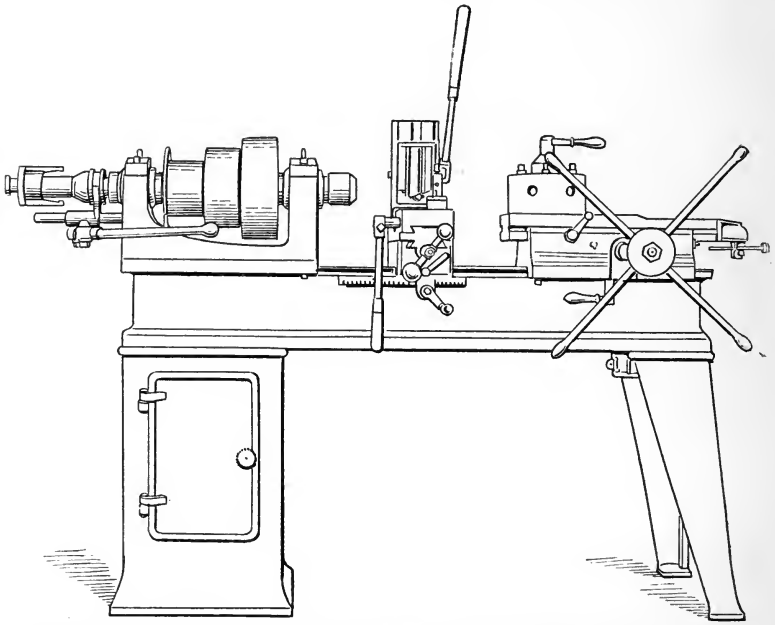


Fig. 304. — 15-inch Forming Turret Lathe with Automatic Chuck, built by the Dreses Machine Tool Company.

cal forming rest, etc., is found very useful, doing the work upon soft metals that the very heavy rest with its horizontal forming tools do for the harder metals, as iron and steel.

In Fig. 304 is shown a 15-inch swing brass forming lathe, with automatic chuck. It is built by the Dreses Machine Tool Company.

The distinguishing feature of the machine is the forming slide, which consists of a base securely clamped to the bed and supporting a horizontal slide fitted in a dovetail and moved by a feed or adjusting screw. Upon the top of this slide is secured an upright

having formed upon it a dovetail, and being adapted to swivel within a small arc. Upon the dovetail on this upright is fitted another slide which is moved by means of a rack, pinion, and lever. This latter carries the forming tool-holder, which is also capable of being tilted slightly and properly clamped when it is adjusted to the right position.

In front of the slide to which the upright is attached is placed an auxiliary small slide, provided with a tool-post and operated by the handle shown at the left. This slide is for use in cutting-off and for other final operations.

For the purpose of adjusting the forming tool to the chucked casting which is to be machined, the entire mechanism can be moved longitudinally on the bed by means of the rack and pinion.

A tightening clamp is provided by which the forming rest may be clamped or released instantly.

An automatic chuck is provided in which work may be gripped and released without stopping the machine. This is very convenient when bar stock is used.

While the machine, as shown, is without back gears, the manufacturers build them with this additional means of increasing the power when such is required.

The countershaft is of the double friction type, whereby six-spindle speeds are obtained.

The plan of adding the forming slide feature to the turret lathe is of much interest in manufacture, since it increases very much the range of the work for which the machine may be used, and with this forming slide so designed as to make it compound in its action, and including also the cutting-off tool-post, its usefulness is still further increased, making the machine as a whole a valuable one on all light machine operations for any work within its range and capacity.

One of the plainest types of turret lathes is built by the R. K. Le Blond Machine Tool Company and is shown in Fig. 305. Its plainness and simplicity are its strongest points. While its initial cost is reduced to a minimum, its capacity for handling a variety of different kinds of work is not correspondingly lessened, as it is well adapted to the lighter kinds of steel work, to cast iron of considerable dimensions, and to work of brass and other softer metals. Not-

withstanding the fact that this limits its range of work somewhat, it is a machine of much practical usefulness as a great variety of light manufacturing comes well within its range, and it can be done as well and as rapidly as on a much more complicated and expensive machine.

The head-stock is long and heavy, supporting boxes for the spindle journals of ample dimensions. The spindle is hollow and of large size so that bar stock may be worked up. The end thrust is taken by ball bearings which minimize friction. The driving-cone has four steps and is adapted for an extra wide belt. The countershaft is of the double friction type, thus giving eight speeds.

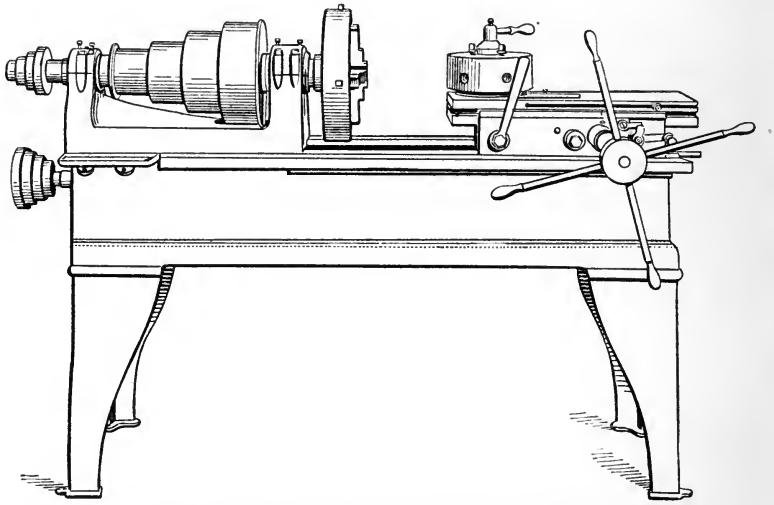


FIG. 305. — 16-inch Plain Turret Lathe, built by the R. K. Le Blond Machine Tool Company.

The turret is very simple, having as few parts as possible in their construction. The turret proper revolves automatically, and when the top slide is flush with the bottom it can be revolved freely by hand and any desired tool brought quickly into position for work. The indexing ring is of large diameter and made of tool steel, hardened and ground, as is also the locking plunger, which automatically adjusts itself for wear. The wear between the turret and the stem upon which it is pivoted is taken up by an adjustable taper bushing.

The top slide is square gibbed and adjusted by a taper gib. The turret base is securely clamped in any position on the bed by two eccentric clamps operated by a wrench from the front of the turret.

The power feed is driven by a belt upon the four-step feed cones. It is positive in its action as a belt feed can be, and is engaged by a lever at the front of the turret and can be tripped to a line in any position by an adjustable stop.

The lathe shown is of 16-inch swing and has a circular turret $8\frac{1}{2}$ inches in diameter. It is drilled with six holes $1\frac{1}{4}$ inches in diameter. The automatic feed is 9 inches. It has a deep and strong bed and is in its design a very substantial machine.

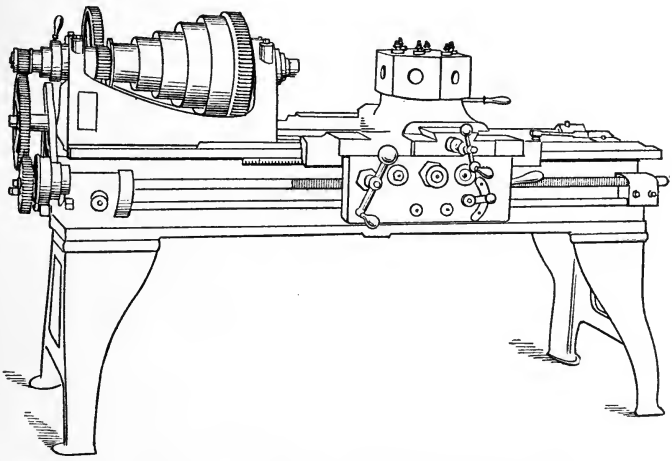


Fig. 306. — 18-inch Engine Lathe, with Turret on Special Carriage, built by the Springfield Machine Tool Company.

As an example of the simplest form of a turret lathe with a hand turret mounted upon the carriage, the one shown in Fig. 306 is given. It is an 18-inch swing engine lathe built by the Springfield Machine Tool Company, and in this particular case a special carriage is shown, although it is very little different from the regular carriage upon which the turret may be as readily mounted.

In this case no cutting-off slide is provided, although one may be readily attached by fitting it to the V's and gibbing it to the bed in the same manner as the carriage is held to the bed.

Some of the special features and dimensions of this turret lathe are as follows, the information for the same being derived direct from the manufacturers.

This lathe is a modification of the standard 18-inch engine lathe, to serve the purpose of a heavy turret lathe, a type which is becoming deservedly popular with the manufacturers of machinery. With the exception of the turret on the carriage and the turret slide, the regular design of the engine lathe has been maintained.

The carriage is very heavy, gibbed to the outside of the bed, both front and back, and is fitted with a turret slide of unusual proportions — 10 inches in width and 16 inches in length, upon which the turret proper revolves.

The turret is hexagonal in form and $10\frac{1}{4}$ inches in width across the flats. The holes in the same may be as large as 2 inches in diameter, and the construction is such that a bar may be passed entirely through the turret. The advantages of this arrangement are too numerous and well understood to require any further explanation. The index pin and clamping lever are on the right side of the turret, and, although entirely out of the way, very convenient for manipulation.

The lathe is provided with power cross feed, as well as longitudinal feed and screw-cutting apparatus, and may be equipped with taper attachment if desired, and hence can perform on chuck or face plate work all the functions usually done with the regular engine lathe, with the advantage of greatly increased production within the same period of time. As a further convenience a taper attachment is added.

This taper attachment is designed with a view to strength and stability, and is attached to the rear of the carriage. It will turn tapers up to 4 inches to the foot.

Such a lathe is an exceedingly useful machine on a great variety of jobs continually occurring in the machine shop, particularly those of which there is a small quantity only to be made. Many of these jobs may have a portion of the work advantageously done on this lathe, and the balance on an engine lathe, both working in conjunction with more efficiency than either would alone.

In Fig. 307 is shown an example of what has been spoken of as a "monitor" lathe or turret head chucking lathe, although it is

used for many kinds of work beside chucking single pieces. It is of 10-inch swing and built by the Pratt & Whitney Company.

These machines are used for drilling, boring, and reaming holes at a much faster rate and with more uniformity than similar work can be done on lathes formerly used for the purpose. They are also largely used to finish parts of machinery, cast or forged pieces of irregular outline and circular cross section, when fitted with the necessary tools.

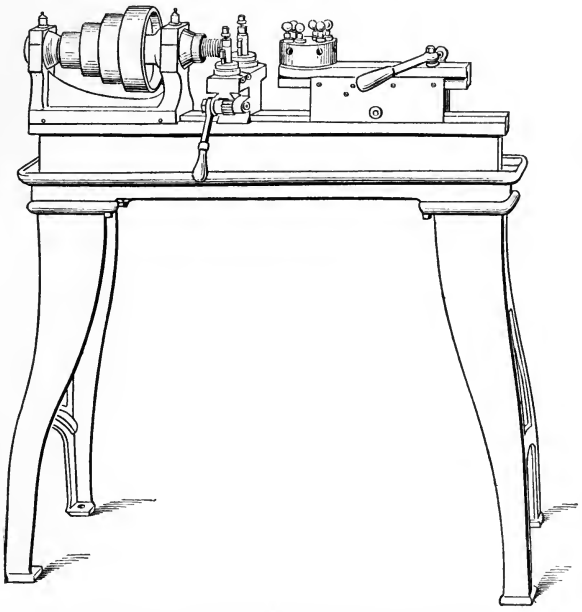


Fig. 307. — 10-inch Monitor Lathe, built by the Pratt & Whitney Company.

They have the same construction as the revolving head screw machines above the bed, but are not usually furnished with the wire feed apparatus for feeding wire or rods through the chuck automatically, or provided with an oil tank, dripping device, etc., as the work usually done upon them does not require the use of oil in cutting. When oil is required these accessories may be readily attached

The heads have provision for vertical and horizontal adjustment of the spindle in case its alignment with the turret holes is

lost by wear. The spindles are made of hard, crucible steel, and are provided with cylindrical boxes lined with genuine babbitt metal.

The larger sizes of these machines are built with back gears, which render them capable of doing much heavier work than the machine shown in the engraving.

With this machine, with its quick acting and convenient hand lever for operating the turret, a very large amount of work can be turned out in a day; in fact, considering the cost of the machine, it is, for all work within its capacity, frequently more efficient than the larger sizes and more elaborate designs of this machine and others of the same general type.

The lever by which the turret slide is operated also automatically effects the revolution of the turret at the end of the return stroke and the beginning of the next forward movement.

There is a cutting-off slide carrying two tool-posts, so that a front and back tool may be used. One of these may be a cutting-off tool and the other a forming tool, if such a tool is needed. Thus it is adapted to turning to size, or several sizes; threading with a die in one of the tool-holding holes in the turret; drilling, reaming, etc., by the turret; and forming and cutting off by the cut-off slide, making it exceedingly useful considering its simplicity and economy.

CHAPTER XXII

ELECTRICALLY DRIVEN LATHES

System of electric drives. Principal advantages of driving lathes by electricity. Group drive versus individual motor system. Individual motor drives preferable for medium and large sized lathes. The Reed 16-inch swing motor-driven lathe. The Lodge & Shipley 24-inch swing motor-driven lathe. The Prentice Brothers Company's motor-driven lathes. General description. Crocker-Wheeler motors. Renold silent chain. The Hendey-Norton lathe with elevated electric motor drive. Special features. A 50-inch swing lathe with electric motor drive designed by the Author. Detailed description Practical usefulness. Not strikingly original, but successful.

One of the more important developments of the modern machine shop tools is the electric drive, with which many of them are equipped. While the system of driving by electric motors has many phases, and all of them most interesting problems, this chapter will be more particularly concerned with the question of individual motors for the machines, leaving out the question of driving a group of machines from a "jack shaft" operated by a single motor, and the plan of driving line shafts in the same manner.

There are many advantages in driving machines, particularly lathes, with individual motors; among them being:

First, the power, and in case of variable speed motors the speed is directly under the control of the operator;

Second, there is economy in the use of power, as none is used to drive "jack shafts" or countershafts;

Third, there is also economy in the use of power as none is consumed except when the lathe is in actual operation; and

Fourth, the wear and tear of belting is either reduced to a minimum or eliminated altogether.

While it may be still an open question whether the "group

drive" system or the individual motor system is the better, particularly for small lathes, there seems to be no doubt of the individual motor system for medium and large lathes, say from 24-inch swing upwards.

In this chapter, therefore, it is proposed to describe and illustrate the modern individual motor system as applied to lathes made by the American up-to-date builder of lathes, and in doing

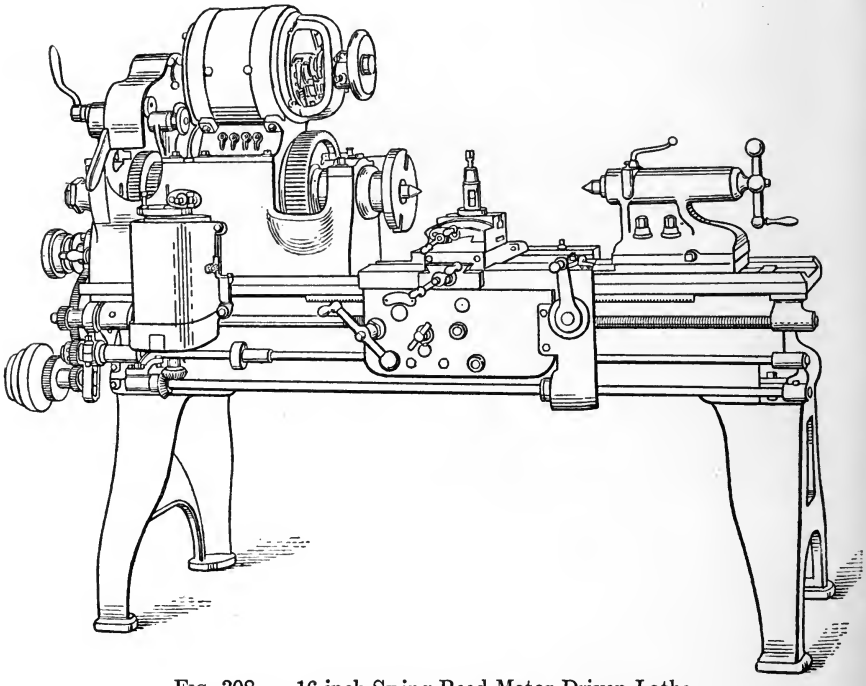


Fig. 308. — 16-inch Swing Reed Motor-Driven Lathe.

this to show those put on the market by the more representative concerns engaged in this business.

In Fig. 308 is shown a 16-inch swing Reed motor-driven lathe. The motor is one-horse power, direct connected, with variable speed. The motor and its controller are built by the General Electric Company. The motor has a speed of from 500 to 1500 revolutions per minute.

As shown in the engraving the motor is geared directly to the main spindle by suitable gearing so that no belt is required. This

method seems preferable to the plan of using a short belt. The noise of fast running gears, in a device of this kind, may be avoided by introducing a rawhide intermediate gear next to the small steel pinion on the motor shaft, by which means the gears will run comparatively quiet even at a very high rate of speed of the motor shaft.

The Lodge & Shipley 24-inch swing motor-driven engine lathe is shown in Fig. 309. This design uses a short belt in driving from

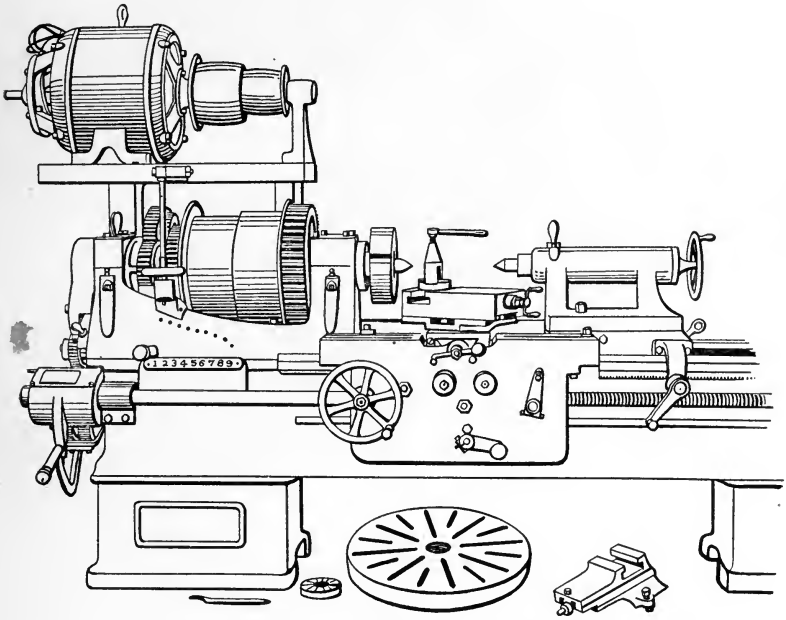


Fig. 309. — 24-inch Swing Lodge & Shipley Motor-Driven Lathe.

a small two-step cone on the motor shaft to the spindle cone. The motor is of the variable speed type with a speed variation of two to one.

The motor is mounted on an overhead bracket directly above the head-stock, pivoted at the rear to two heavy standards bolted on to the back of the bed, and is connected to the driving pulley by a short, wide belt, in which sufficient tension for driving is obtained by means of the adjusting screw with a hand wheel at the front of the head-stock.

When this system is used the cone pulley has two steps, and two sets of back gears are provided, so that the combination affords a total of six speed changes, two with the lathe out of gear and two with each of the back gears in. By varying the speed of the motor, either through the introduction of field resistance or by use of one of the multiple voltage systems, intermediate speeds in each range are obtained, the number of which depends only on the number of points in the controller. With a 20-point controller, 120 distinct spindle speeds are thus afforded.

This company also equip their lathes with constant speed motors, for which purpose they mount the motor at the rear of the head-stock near the floor. From a small pulley on the motor shaft a belt runs up to a large pulley on a countershaft located directly in the rear of the head-stock. This countershaft carries the usual speed cone, from which a short belt connects with the spindle cone in the usual manner. The countershaft speed is from 125 to 200 revolutions per minute.

In buying a motor-driven lathe, the purchaser has usually to decide between a direct-connected and a belt-connected lathe, and between a constant speed and a variable speed motor. The use of a constant speed motor direct geared to the lathe is practically prohibited, on account of the mass of gearing necessary to secure sufficient speed changes.

This may be obviated by using the countershaft as above arranged, although it is well known that short belts are objectionable on account of the high tension that must be maintained to render them capable of transmitting the required power to properly operate the lathe.

The Prentice Brothers Company equip their 14, 16, 18, 20, and 22-inch swing engine lathes with a motor drive device which is shown in Fig 310.

In this case the motor is under the bed and close to the head cabinet. Eight changes of spindle speed are provided for by means of a series of gearing located in the head-stock of the lathe. All of these speeds are available without stopping the lathe. The gearing is so arranged that it is impossible for the operator to interlock any conflicting ratios of gearing. This is an advantage that is greatly appreciated, as it removes all possible danger of break-

age to the gearing or the clutches in the driving mechanism of the machine.

A mechanical reverse is provided and may be operated from the carriage of the lathe so that the operator can start, stop, and reverse the direction of the spindle without stopping the motor. This is a great saving of power over the method commonly used, that is, reversing the motor, stopping and starting the motor when stopping, starting, and reversing the lathe.

For operating this lathe the manufacturers recommend a constant speed motor with either direct or alternating current, although a direct-current motor, with a variation allowing an increase of

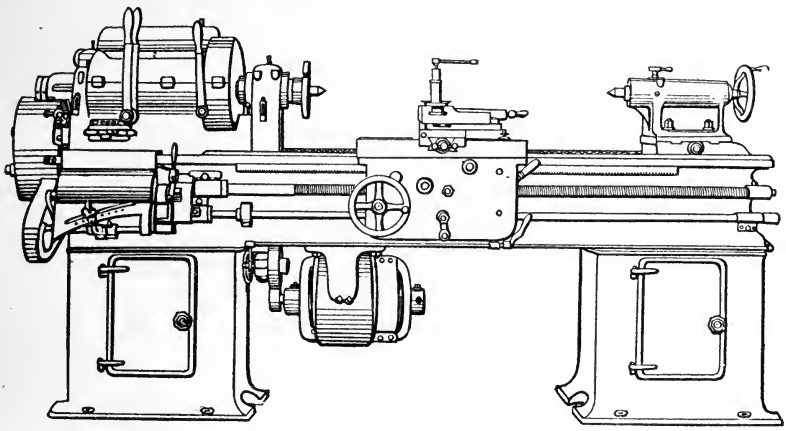


FIG. 310. — 18-inch Swing Prentice Motor-Driven Lathe.

50 per cent in the speed, can be used to some advantage and would divide the steps of the mechanical speed variation into five or six additional changes, giving 40 or 48 changes of speed in all.

In general practice, however, this great number of speeds is not needed. The advantages of using a constant speed motor are numerous beyond the matter of efficiency, as in most cases variable speed motors are of a special nature and it is much more difficult to secure repair parts than it is with the constant speed motor, as one can usually have the parts needed shipped directly from stock and without any delays.

Another consideration should be noted. The wear upon the variable speed reversing controller is considerable when we take

into consideration the number of times that the lathe is stopped, started, and reversed each day

The greatest advantage is that the induction motor is without commutator troubles, which is the main cause of difficulties with all direct-current motors.

A lathe capable of doing at one setting the operations that would require eight or more settings of an ordinary engine lathe is the 24-inch semi-automatic turret lathe, manufactured by the American Turret Lathe Company and shown in Fig. 311 as a good example of this class of machines so driven.

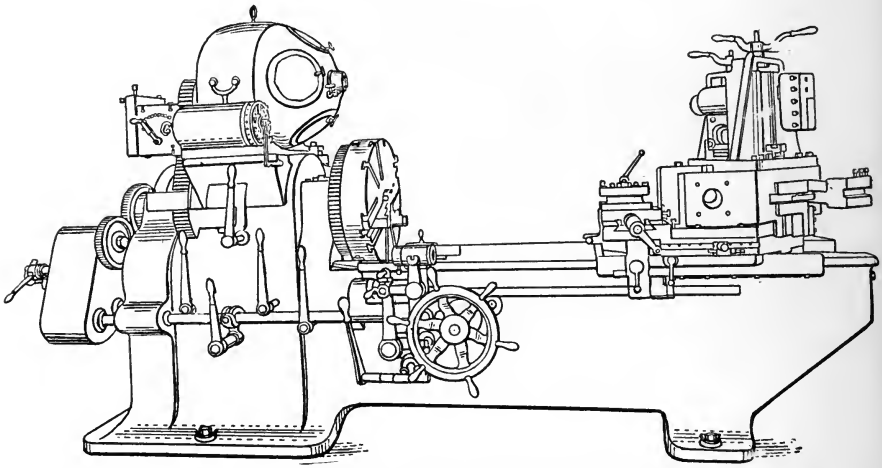


FIG. 311. — Heavy Motor-Driven Turret Lathe built by the American Turret Lathe Company.

Being intended for heavier work than is usually imposed upon a turret lathe, it has a massive bed construction, a large turret, and is designed to swing 27 inches for a distance of 12 inches from the chuck.

Twelve rates of feed and feed reverse and eight speeds of the spindle are possible with each speed of the motor. The gear combinations for all these are protected and may be operated to effect a change in speed while the machine is running. The levers for the various gear clutches are shown under the head. The turret has universal facing heads and provides for thirteen tools, though seldom more than five are used at a time.

There is an auxiliary turret which will accommodate four tools and has power cross feed on one side of the turret. The latter has power traverse in either direction by a separate motor, and a slower travel through the feeding mechanism driven from the spindle. Rotating, indexing, and clamping of the turret head are all automatic, and an independent "knockout" or feed stop serves each face.

The spindle is driven through a Renold silent chain by a ten horse-power Crocker-Wheeler semi-enclosed motor mounted above the head-stock. An M. 12 controller in the current supply allows the motor twelve speeds, ranging from 876 to 130 revolutions per minute.

With the combination of electrical and mechanical means the highest and lowest possible chuck speeds are 90 and 1 1-5 revolutions per minute, respectively. For the operation of the turret a three horse-power Crocker-Wheeler fully enclosed motor is used. This runs continuously at a constant speed of 1,000 revolutions per minute on a two-wire supply, and drives a steep-pitch lead screw through bevel gearing. A longitudinal shifting of the driven shaft clutches one or the other of the two bevel gears, producing direct or reverse rotation, or in the central position releases both.

The Hendey-Norton arrangement of an elevated electric motor operating a countershaft is shown in Fig. 312.

The electric-motor drive, as illustrated, gives all the advantages to be had from regular countershaft drive. It will be noticed that the motor is of the back geared type. Carried on the end of the commutator shaft are two rawhide pinions of different diameters, driving two large gears on the countershaft of the motor, the gearing being properly proportioned to give the required driving speeds to the countershaft.

These large gears run smoothly on the shaft. Their inner formation is that of the friction clutch pulleys used on their shapers, and carried between them, keyed to but sliding on the shaft, is a friction clutch, which is thrown into connection with either gear as desired, being operated by the depend'ng shipper and handle extended back and supported in a ring at the end of the lathe, as shown.

The clutch is also fitted with the usual locking spring and point.

We thus have two speeds for the countershaft, affording the sixteen changes for the lathe spindle. These are accomplished with the motor running at constant speed, thus maintaining its maximum efficiency at all times.

The reversing device for the carriage is operated at the side of the apron, which allows the spindle to run in the one direction, and dispenses with the necessity of wiring the motor for backward drive, an item of expense and complication which is avoided.

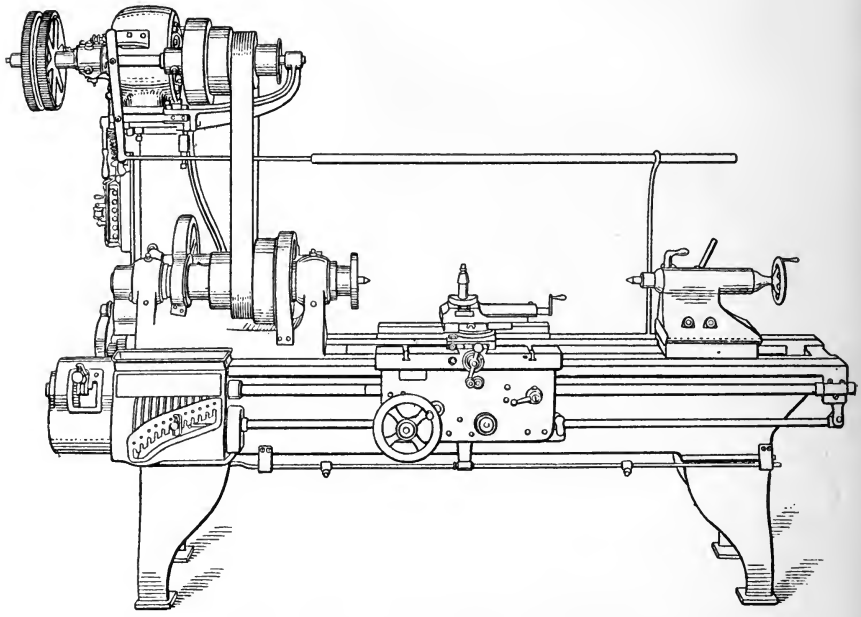


FIG. 312. — Hendey-Norton Motor-Driven Lathe.

The standard carrying the motor is rigidly bolted to the lathe bed, and, being strongly webbed, is free from any disturbing vibration. The motor is directly attached to a hinged plate on the top of the standard.

At the front end of the plate there is carried a short-throw cam which allows the plate a slight drop and consequent loosening of the belt when it is desired to shift from one step of the cone to another. The cam rides upon adjustable posts which afford a means of taking up any slight stretch occurring in the belt. The motor back gear

shaft is supported at pulley end with an out-board bearing, which prevents any springing of the shaft when the belt is used on the smaller steps of the cone.

The workmanship on the electric motors and their connections, like the work on the lathes and other product of this company, is first class, and the entire outfit is a good example of mechanical work, although it cannot be said that the design of the device, with its heavy looking bracket supporting the countershaft and motor, is altogether pleasing to the eye. It has rather a top-heavy appearance.

The following illustration, in which Fig. 313 is a front elevation

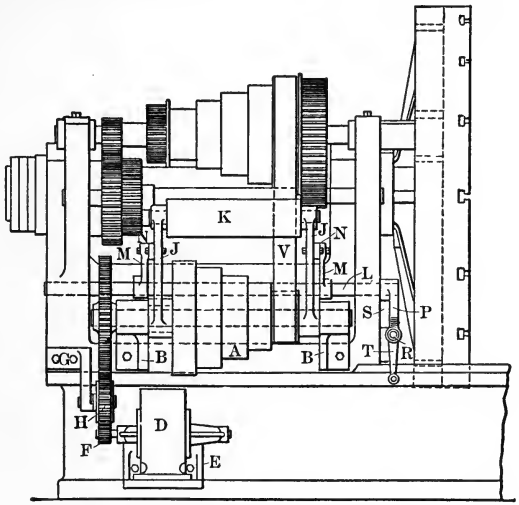


Fig. 313. — Front Elevation — Electric Drive for 50-inch Lathe, designed by the Author.

and Fig. 314 an end elevation and partial section, is of an electric drive designed by the author for a 50-inch swing lathe.

The advantages of having a machine tool, particularly a large one, driven by its own individual electric motor are many, however the electric drive may be arranged. They are greater if the machine was originally designed to be so driven, and particularly with a variable speed motor. But it sometimes happens that we are called upon to arrange an electric drive to a machine already built and perhaps in use in the shop. We may also be required to drive

it with a constant speed motor, and must therefore make proper provisions for speed changes.

Under these conditions a large lathe had to be arranged for parties who insisted that the cone pulley in the head-stock should be replaced by a series of gears of varying diameters and so arranged as to engage any one of a second series of gears located on a supplementary shaft in front of them, the gears being placed at unequal intervals, the smallest somewhat greater than the width of their faces from each other. The lathe was so arranged and successfully used, yet the necessary complication of the shifting

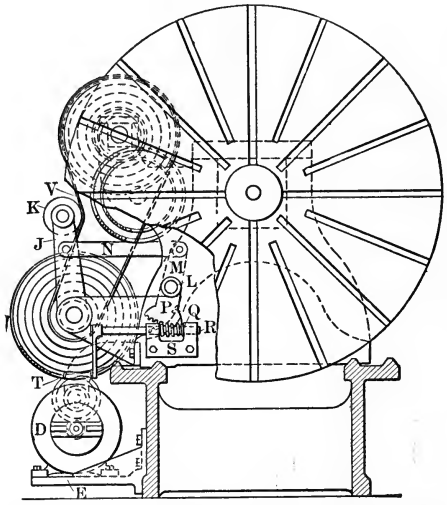


FIG. 314. — End Elevation of 50-inch Lathe with Electric Drive designed by the Author.

apparatus, and the difficulty of readily bringing the proper gear into engagement with its fellow by sliding the gear longitudinally, rendered the device somewhat clumsy and inconvenient, and was the cause of some bad language on the part of the man who ran it.

The next occasion on which a similar problem arose the customer was not insistent upon any partiular plan, only he "didn't want it like the other one." The motor to be used was of constant speed and the following device was adapted in attaching it to the lathe, as shown by the front elevation in Fig. 313, and the end elevation in Fig. 314.

The countershaft cone A is mounted on a shaft journaled in the brackets B, B, attached to the head-stock, as shown. At the rear end of this shaft is fixed a gray-iron gear C. The motor D is supported upon a bracket E attached to the lathe bed and carries on the end of its shaft the steel pinion F. Between the pinion F and the gear C, and journaled on the bracket G attached to the head-stock, is a rawhide gear H engaging both of them. This is introduced to avoid the noise which would otherwise be caused by the fast-running pinion F on the motor shaft. The gear H is constructed with a gray-iron flange on each side, one flange having formed upon it a hub passing through the rawhide blank and the opposite flange, and the whole firmly secured together by six flush-headed screws, the object of this construction being to furnish a good bearing on the stud upon which it runs and also to furnish proper support for the ends of the teeth.

Upon the bosses of the brackets B, B, are formed projecting sleeves upon which are journaled the arms J, J, in the upper ends of which is journaled the belt-tightening roller K, which is composed of a piece of 5-inch extra thick wrought iron pipe, provided with gray-iron heads through which its shaft passes. Through the two end portions of the head-stock, holes are drilled in which is journaled the rock shaft L, upon which are fixed the two levers M, M, the upper ends of which are connected to the arms J, J, by the connecting rods N, N. Upon the front end of the rock-shaft L is fixed the worm segment P, which engages the worm Q, the shaft R of which is journaled in the bracket S fixed to the front of the head-stock, as shown in Fig. 314. Upon the outer end of the shaft R is fixed the crank T for operating the belt-tightening device.

The belt V is cemented instead of being laced, to facilitate its smooth running. By a backward turn of the crank T the belt V is rendered slack enough to be changed from one step of the cone to the other, and a forward turn of the crank tightens it as much as may be necessary to drive the lathe.

In practice it was found that the operator preferred to use the crank for stopping and starting the lathe to examine and caliper his work rather than to use the electric switch or the rheostat, claiming that it was more convenient to allow the motor to continue to run and start the lathe gradually by tightening the belt slowly for

that purpose, and we must admit that the operator of a machine, in his daily experience, frequently finds convenient ways to "do things" that the designer or the foreman may entirely overlook.

While the device here shown is simple, and no claim is made of anything strikingly new or original, it has succeeded admirably and given good satisfaction to the proprietors as well as to the employees of the shop where it is in use, and will be found an economical, convenient, and efficient method of applying the electric drive to existing lathes.

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